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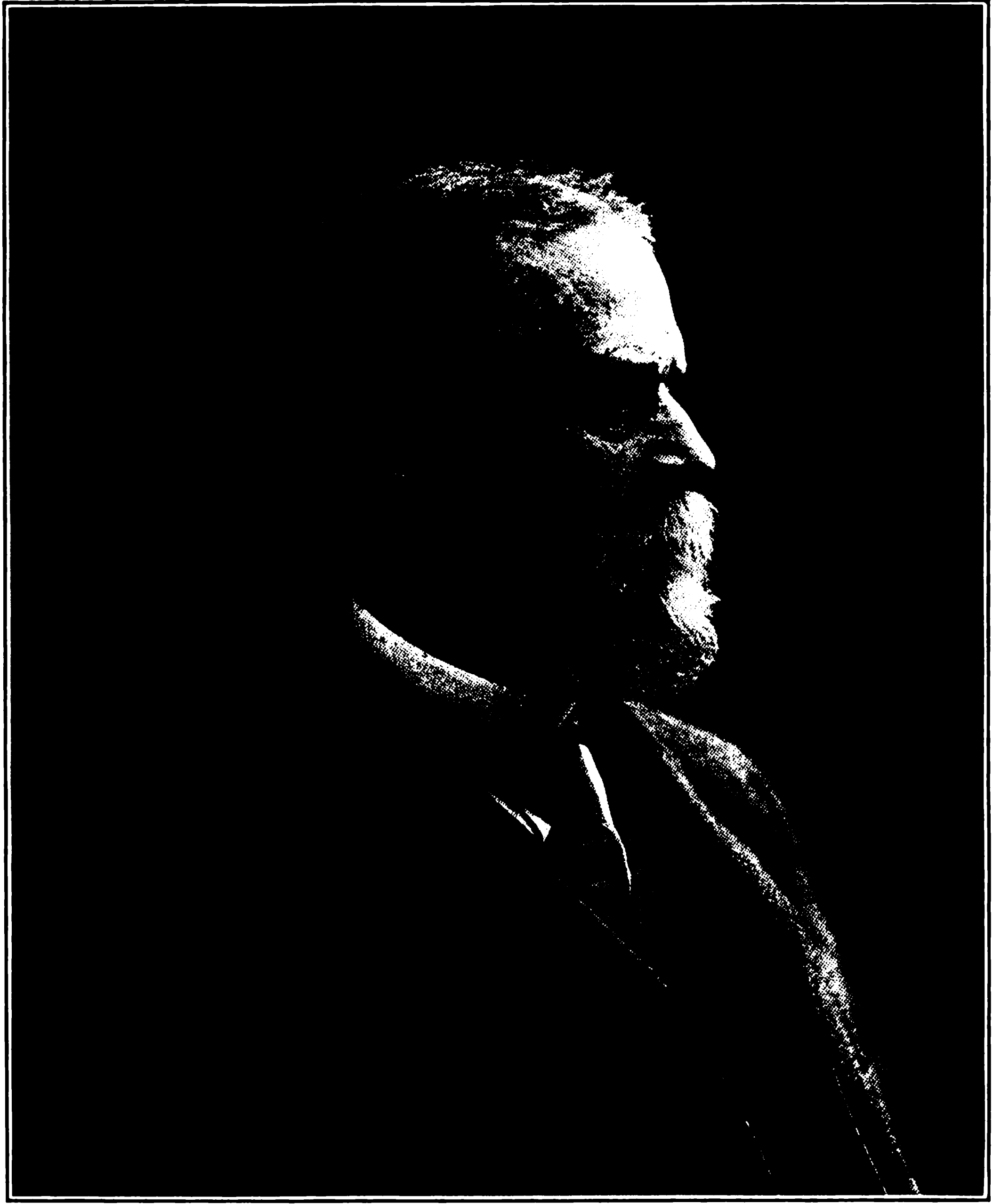

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National Academy of Sciences (U.S.)

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PREFACE.

In accordance with a rule of the National Academy of Sciences, it is the duty of the President, upon the death of a member, to select some one to prepare a biographical memoir of the deceased.

Such memoirs have been collected in permanent form from time to time for the use of the Academy and for distribution among reference libraries in this country and in Europe. Each biography is supplemented by a list of the more important publications of the deceased member, and is accompanied by a likeness and a facsimile of his signature.

The present is the seventh volume of the series and contains fourteen memoirs. It should be stated that all of these memoirs here brought together in book form have been issued separately.

With the close of this volume and at the end of the first half century since the organization of the Academy, one hundred and eight biographies have been published.

ARNOLD HAGUE,
Home Secretary.

WASHINGTON, April 15, 1913.

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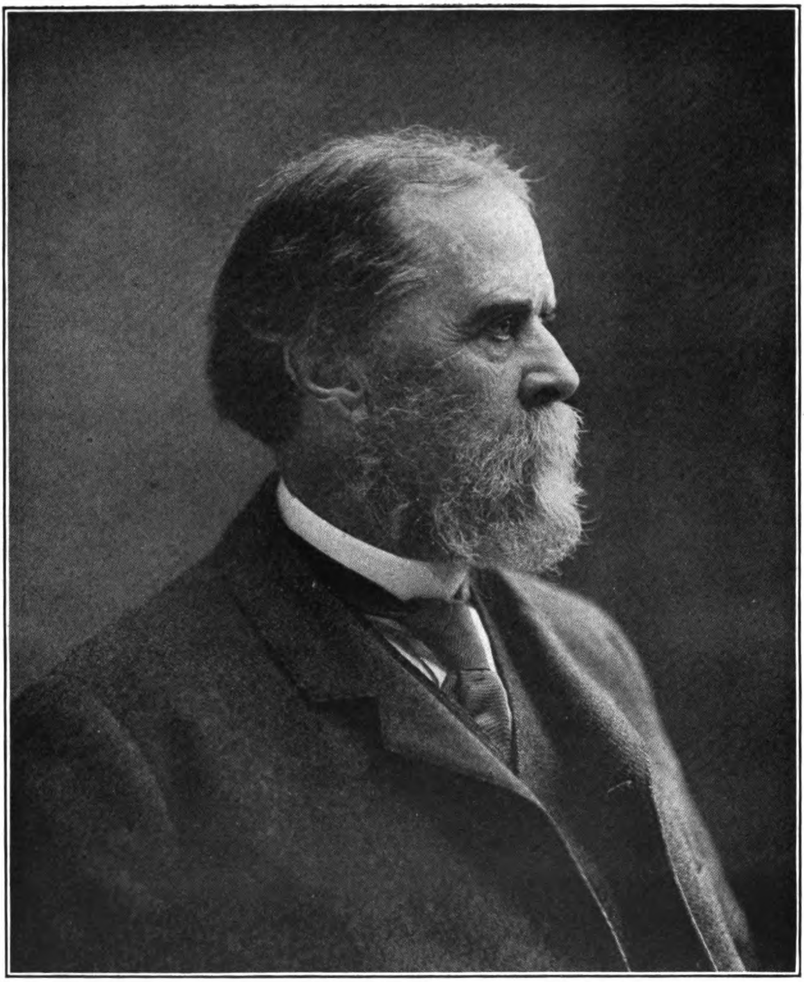

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Wolcott Gibbs

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NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VII

BIOGRAPHICAL MEMOIR

OF

WOLCOTT GIBBS

1822-1908

BY

F. W. CLARKE

CITY OF WASHINGTON
PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES
February, 1910

WOLCOTT GIBBS.*

Oliver Wolcott Gibbs,† a charter member of the National Academy of Sciences, and at one time its president, was born in the city of New York, February 21, 1822. His father, Colonel George Gibbs, was a man of some wealth, who owned a large country place at Sunswick, on Long Island, not far from the then small metropolis. He was an enthusiastic mineralogist, and gathered a collection which, ultimately sold to Yale College, became the nucleus of the great cabinet since made famous by the labors of the two Danas, Brush, and Penfield. It was perhaps the control of the Gibbs collection which first led J. D. Dana to write his classical "System of Mineralogy." Colonel Gibbs, for whom the mineral *gibbsite* was named, was himself the author of several memoirs upon mineralogical subjects; and his oldest son, also named George, achieved some reputation as a geologist and as a student of ethnology. Wolcott Gibbs was born into an atmosphere of scientific interests, and his early associations must have influenced his choice of a career. A taste for science ran in the family.

Laura Gibbs, the mother of Wolcott, came of distinguished ancestry. Her father, Oliver Wolcott, rose through various positions to that of Secretary of the United States Treasury; a post which he held during the latter part of Washington's administration and well into the administration following. He then became a justice of the United States Circuit Court, and during the last ten years of his life he was Governor of the State of Connecticut. His father, another Oliver, was a magistrate, a major general of militia, a member of Congress, and a signer of the American Declaration of Independence. He too was a Governor of Connecticut, and so also was his father, Roger Wolcott, the first noteworthy member of the line. In

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*** Read before the National Academy of Sciences, November, 1909.**

† He dropped the Oliver early in his career.

short, the ancestors of Wolcott Gibbs were people of far more than average ability, who had the confidence and esteem of their fellow-citizens, and were therefore entrusted with positions of high rank and responsibility. Even though there was no commanding genius among them, no man of world-wide fame, they at least left to their descendants a legacy of lofty examples, well worthy of emulation. We may differ in our opinions as to the significance of heredity; but we can recognize the fact that Gibbs received from his forbears a sound mind in a sound body, together with traditions of well doing that could not be disregarded. A good ancestry is a good beginning for any man.

In his early environment Gibbs was also fortunate. Although he was only eleven years old when he lost his father, his mother survived for many years, and gave him the best of opportunities for healthy development. She was a woman of strong character and unusual ability, and her home became a center in which the best intellectual society of New York was to be found. Her character, forceful, positive, patriotic, and public spirited, was reflected in that of her son.

The early childhood of Wolcott Gibbs was largely spent at his father's estate of Sunswick, where, as he tells us in a brief autobiographical note, "he was often occupied with making volcanoes with such materials as he could obtain, and in searching the stone walls . . . for minerals, and the gardens and fields for flowers." At the age of seven he was sent to a private school in Boston, where he was under the care of a maiden aunt, whose sister had married the famous Unitarian divine, William Ellery Channing. The winters were passed in Boston, and the summers with the Channings at their country place near Newport, Rhode Island. Here again he was surrounded by choice influences, and saw many distinguished people. The reputation of Dr. Channing attracted many visitors, including more than a few from abroad, and the boy must have come to some extent in contact with them. Being but a child, he may not have understood or appreciated his opportunities, but his imagination could not have been entirely unaffected. His early associations foreshadowed his later career.

When he was twelve years old, Gibbs returned to New York, and began his preparation for college. In 1837 he entered Columbia College as a freshman, and graduated in 1841. It was in his junior year that he published his first scientific paper, a description of a new form of galvanic battery, in which carbon was used, probably for the first time, as the inactive plate. This achievement, unimportant as it may seem now, was really remarkable in two ways; first, on account of the youth of the author, and secondly, because of the conditions under which the work was done. In those days the American colleges, like the public schools of England, were intensely classical in their aims, and science received the minimum of attention. Latin, Greek, and mathematics ruled the curriculum, with only a smattering of other subjects. Even in the classics literature was subordinate to grammar, and as for the modern languages they were almost if not quite ignored. What science was taught was taught by lectures and text-book recitations, for the era of laboratory instruction had not begun. That a pupil of eighteen should make an original investigation under such conditions was surprising, but it showed the irresistible tendencies at work in his mind. The early impulses, received from his father, could not be overcome.

After receiving his bachelor's degree young Gibbs went to Philadelphia, where he served as assistant in the laboratory of Robert Hare, the well-known inventor of the compound blowpipe, who was then Professor of Chemistry in the Medical School of the University of Pennsylvania. Gibbs' purpose was to fit himself for holding a similar professorship, and so, after several months of experience with Hare, he entered the College of Physicians and Surgeons in New York, and in 1845 became a full-fledged Doctor of Medicine. He never practiced, and probably never intended to do so, for the study of chemistry was the main purpose of his life, and his medical studies were only a means to an end. Indeed, they stood him in good stead when, many years later, in collaboration with Drs. Hare and Reichert, he undertook to study the physiological effects of definitely related chemical compounds on animals.

Up to this point the training of the future chemist had been only preliminary, a laying of foundations, so to speak. In his time advanced scientific education was not easily obtained in America, and ambitious students who were able to do so sought their higher opportunities in Germany. Accordingly, Doctor Gibbs, as we must now call him, went abroad, and began by spending several months with Rammelsberg in Berlin. After this he studied for a year under Heinrich Rose, which was followed by a semester with Liebig at Giessen. He next went to Paris, where he attended lectures by Laurent, Dumas, and Regnault, and in 1848 he returned home, ready to begin the real labors of his life. Among his teachers the one who most impressed him was Rose, whom Gibbs greatly admired, and who doubtless gave his pupil his strong bias towards analytical and inorganic chemistry. From his other teachers, however, Gibbs acquired a breadth of view and an insight into different fields of research, which made him all the stronger as an investigator. He was a chemist in the largest sense of the term, and not a mere sub-specialist.

After returning to America, Gibbs first delivered a short course of lectures at Newark College, in Delaware. Then, in 1849, his native city claimed his services, and he was appointed professor of chemistry in the newly established Free Academy, now the College of the City of New York. He remained in this position for fourteen years, chiefly occupied in teaching elementary students, and at first doing, apparently, little else. He was not idle by any means, but he was finding himself, and his time was not wasted. It was in 1857 that his first really notable research was given to the world, namely, the joint memoir of Gibbs and Genth on the ammonio-cobalt bases. Of this I shall speak more at length later. In 1851 he became an associate editor of the American Journal of Science, and began the preparation of a series of abstracts which brought the results of foreign investigations to the attention of American readers. These abstracts amounted in all to about 500 pages, and were, despite their brevity, conspicuously clear and comprehensive. In 1861 the first of his papers upon the platinum metals appeared, and his reputation was at last firmly established.

Notwithstanding his recognized ability, Doctor Gibbs, during this period, suffered one serious disappointment. The chair of chemistry in his *alma mater,* Columbia College, became vacant, and Gibbs, backed by the recommendations of nearly all the leading men of science in America, was a candidate for the position. On very questionable grounds his candidacy was rejected, and a man of smaller attainments received the appointment. This was unfortunate for Columbia, but not altogether so for Gibbs. In 1863 he was called to a very desirable post, the Rumford Professorship in Harvard University. Nominally, this was a professorship of the "Application of Science to the Useful Arts," but its incumbent, in addition to lecturing upon heat and light, was expected to take charge of the chemical laboratory in the Lawrence Scientific School, and this gave Gibbs a great opportunity for usefulness. Furthermore, the position was a delightful one upon its social side, and he was thrown into close association with many congenial spirits. There were Louis Agassiz the zoologist, Asa Gray the botanist, Jeffries Wyman in comparative anatomy, Benjamin Pierce in mathematics, and J. P. Cooke in chemistry. Literature was represented by Longfellow, Lowell, Holmes, and other less famous writers; altogether an aggregation of distinguished men which could not be matched elsewhere in America and equalled at few places in the world. Gibbs was among his peers, and in a place where his worth could be fully appreciated.

Doctor Gibbs remained in charge of the Scientific School laboratory for eight years, and during that time his researches were for the great part, although not exclusively, devoted to analytical methods. The school was technically a department of Harvard University, and yet its work was carried on quite independently. The students were usually men of definite purposes, who knew what they wanted and went where it could be best obtained. They went to Agassiz for zoology, to Gray for botany, and to Gibbs for chemistry, because those men were the leaders in their respective subjects, and they worked, not in classes, but as individuals. The students in chemistry had little or nothing to do with the students in other branches, for the school was distinctly professional in its aims. Teachers from other institutions, seeking to enlarge their knowledge, were often among them. Gibbs was now training men who intended to become chemists, and some of them were qualified to assist in his investigations. Moreover, he was not overloaded by numbers, for he rarely had more than twenty students in attendance at any one time. There was one assistant, to relieve him of routine work; his lectures upon light and heat cost him little effort, and he was therefore able to devote his energies to research more advantageously than ever before.

It was my good fortune to have been a student under Gibbs during the greater part of four years, between 1865 and 1870. I may therefore be permitted to speak of his teaching from my own experience, believing that in such matters the personal note is not without value. There was nothing unusual about the course of instruction so far as ordinary details went, for that necessarily followed certain well established lines. Most of the students had already gained some elementary knowledge of chemistry; their work began with the usual practice in analytical methods and chemical manipulations, and as the men showed capacity they were admitted to the confidence of their master and aided him in his investigations. This procedure may seem commonplace enough today, but in the years of which I speak it was new to American institutions, and was looked upon doubtfully by some of the old-fashioned pedagogues. The students who chose to do so attended the chemical lectures of Cooke in Harvard College, but that work was wholly optional. The only formal examination was the final examination for the bachelor's degree, and therefore there was little or no cramming. Gibbs apparently believed, although his belief was not stated in set terms, that a good teacher who kept in touch with his pupils should know perfectly well where they stood, and no examination could tell him anything more. In fact, examinations are often misleading, for the reason that even a fine scholar of nervous temperament may become confused and helpless during the ordeal, and fail to answer the simplest questions. On the other hand a poor student with a fair memory may cram for an examination, pass triumphantly, and amount to nothing afterwards. The real examinations under Gibbs were daily interviews, when he visited each student at his laboratory table and questioned him about his work. This, together with the reported analyses, gave the teacher a clear conception of the true standing of each man. The fewness of the pupils was a distinct advantage, for all worked together in one room, beginners and research students often side by side. The result was that they learned much from one another, and there were many discussions among them over the burning problems of the day. The men were taught to stand on their own feet, and to think for themselves, laying thereby a foundation for professional success which was pretty substantial. The course of instruction had no definite term of years prescribed for it, and graduation came whenever the individual had done the required amount of work and submitted an acceptable original thesis. The final examination was usually oral, each man alone with his master, and was conducted in an easy conversational way which tended to establish the confidence of the candidate from the very beginning. In my own case, I remember that the questions covered a fairly broad range of chemical topics, and at the end of it Doctor Gibbs drew me into a sort of discussion or argument with him over the then modern doctrine of valency. I now see that his purpose was not merely to ascertain what I had read on the subject, but what I really thought about it, if indeed I was entitled to think at all. Gibbs invariably treated his students, not as so many vessels into which knowledge was to be poured, but as reasonable beings, with definite purposes, to whom his help must be given. That help was never denied to any man who showed himself at all worthy of it. The research work in which the advanced students shared, and for which they received public credit, served to teach them that chemistry was a living and growing subject, and to train them in the art of solving unsolved problems. They were taught to *do,* and encouraged to *think,* and if, on going forth into the world, they sometimes felt themselves qualified to revolutionize all science, their vanity did no harm and was soon remedied. An enlightened ignorance is only gained with advancing years, and the enthusiastic beginner cannot be expected to appreciate it. It is the last polish that the ripened scholar acquires.

What now is the meaning of this long disquisition upon the methods of Gibbs Laboratory? What was there at all unusual in his teaching? Nothing, perhaps, from a modern point of view, but much that was new to America in the middle sixties. It was Gibbs' peculiar merit that he, more than any other one man, introduced into the United States the German conception of research as a means of chemical instruction, a conception which is now taken as a matter of course without thought of its origin. Gibbs worked with small resources and no help from outside; he was a reformer who never preached reform; his students rarely suspected that they were doing anything out of the ordinary; but they had the utmost confidence in their master, and took it for granted that his methods were sound. There was nothing of the drill master about Gibbs, no trace of pedantry, no ostentation of profound learning; but the students never doubted his sincerity of purpose and interest in their work, or questioned his ability as a teacher. As for Gibbs himself, it is doubtful whether he ever imagined that his teaching was at all remarkable. He did what was to him the natural and obvious thing to do, simply and without pretense, and the results justified his policy. The success of his students is perhaps the best monument to his memory.

In 1871 the chemical instruction at Harvard University was reorganized, in spite of strong protests from Gibbs and other scientific leaders. The laboratory of the Scientific School was consolidated with that of the College, and Gibbs had no more students in chemistry. His work was limited to that of the Rumford professorship—a change which left him more time for personal research, but took from the students the inspiration of his teaching. The change may have been justifiable on grounds of economy, but it was otherwise a mistake, and it was so recognized among chemists generally. The economy was only financial; but an important asset of the University, the ability of a great teacher, was not turned to the best account. Fortunately for Gibbs he had independent means, although he was not a rich man, and he was able to equip a small laboratory of his own and to employ a private assistant. In that laboratory he carried out those brilliant researches upon the complex inorganic acids, which marked the culmination of his career. The equipment was most modest, and in some respects it reminded one of the famous kitchen of Berzelius. Indeed, Gibbs' favorite piece of apparatus was that homely utensil, a cast iron cooking stove, which served for several useful purposes. Precipitates could be dried in the oven, crucibles were buried in the coals, water was kept hot on top of it. As an instrument of research it was neither elegant nor orthodox, but it did the work, and what more could be desired? Gibbs adapted himself to circumstances, and cared little for the instrumental refinements which so many chemists seem to regard as necessary. The real essentials were provided; mere conveniences, the luxuries of research, he could do without.

For sixteen years after the closing of the Scientific School laboratory, Doctor Gibbs lectured to small classes of students upon the spectroscope and on thermodynamics. In 1887 he retired, as Professor Emeritus, and went to live in his house at Newport, where he had been accustomed to spend his summer vacations. His private laboratory was moved to Newport also, and there he continued his investigations until, enfeebled by old age, he was obliged to rest on his laurels. As a recreation he cultivated a flower garden, and was proudest of his roses. In that way his love of the beautiful found its chief expression. On December 9, 1908, he passed away, at the age of nearly 87. His wife, whose maiden name was Josephine Mauran, and whom he had married in 1853, died several years earlier, leaving no children.

So much for biography. It now remains for us to consider the contributions of Gibbs to science, and to trace their relations, so far as may be practicable, to later work. An investigation never stands alone; each one touches other investigations at several points; and its worth may be greatest as the progenitor of other researches. The suggestiveness of a discovery, its influence in stimulating thought, is fully as important as its immediate outcome. It is a seed, whose value is finally determined by its fertility.

Gibbs' first paper, a "Description of a new form of magneto-electric machine, and an account of a carbon battery of considerable energy," published when he was a junior student at Columbia, has already been mentioned. In 1844 he attempted to discuss the theory of compound salt radicles, and in 1847, while a student abroad, he published a number of mineral analyses. In 1850 Gibbs pointed out the interesting fact that compounds which change color when heated, do so in the direction of the red end of the spectrum. In 1852 he published the first of his memoirs upon analytical methods, in which he proposed the separation of manganese from zinc by means of lead peroxide; and in 1853 he prepared, and partially described, an arsenical derivative of valeric acid. In all of this work there was nothing of great importance, but its varied character is suggestive. It represents the efforts of an active mind, feeling its way under unfavorable conditions, and not quite sure of its true capacities. Mineral chemistry, organic chemistry, analytical chemistry, chemical theory, and physics in turn attracted his attention during this formative period of his career. It was in the great research upon the ammonio-cobalt bases that Gibbs finally found himself and forced the world to recognize his ability. His apprenticeship was ended, and his work as a master had begun.

The first of the ammonio-cobalt compounds, the oxalate of luteocobalt, was prepared by Gmelin in 1822, the very year in which Gibbs was born. It was supposed, however, to be a salt, of cobaltic acid, and several other chemists, who studied it later, shared in the same misapprehension. In 1847, Genth, then at Marburg, discovered other salts of these bases, but it was not until 1851, after his emigration to America, that he published his description of them in a rather obscure journal. Genth was the first to recognize the true character of the new compounds, and he was followed by Claudet and Fremy, the three chemists working independently of one another and almost simultaneously. Up to this point Fremy's work was the most exhaustive, but it left much to be desired.

Genth had identified the two bases since known as luteocobalt and roseocobalt. In 1852 Gibbs discovered the salts of xanthocobalt, which contained, in addition to the ammonia, a nitro group. It was therefore quite natural that the two chemists should join forces, and in 1856 their celebrated memoir appeared. In this memoir thirty-five salts were described, of the four bases roseocobalt, purpureocobalt, luteocobalt, and xanthocobalt, with adequate analyses, and in eleven cases crystallographic measurements by J. D. Dana. The roseo- and purpureo-compounds were for the first time clearly discriminated, although they were supposed to be isomeric—a misconception which could hardly have been avoided at that time. There was also an elaborate theoretical discussion upon the constitution of the bases, but that also was premature. The fundamental theories of structure were yet to be developed. Blomstrand, Jörgensen, and Werner, in later years, utilized the data of Gibbs and Genth, and Werner especially made the ammonio-cobalt compounds the basis of his famous theory of the constitution of the metalamines. Gibbs and Genth laid the foundations on which later investigators have built an imposing structure.

Gibbs was an experimentalist rather than a theorist, and yet he neither underrated nor avoided theory. In 1867 he published a paper upon atomicities, or valences, as they are now called, in which he developed the idea, then vaguely held by others, of residual affinities. He argued in favor of the quadrivalency of oxygen, and showed that on that supposition a molecule of water must be bivalent, and any chain of water molecules would be bivalent also. He then considered ammonia in the same way, with the two bonds of quinquivalent nitrogen unsatisfied. Ammonia, therefore, was weakly bivalent, and so, too, would be a chain of ammonia molecules. This conception he applied to the interpretation of the ammonio-cobalt bases, and so, too, did Blomstrand two years later. If we consider theories of this kind not as finalities, but as attempts to express known relations in symbolic forms, we must admit that Gibbs' conception was useful, and served well for the time being. That it has given way to other views more in harmony with modern discoveries, is not at all to the discredit of its author. In the later papers by Gibbs, published in 1875 and 1876, he made good use of his hypotheses, and described many more ammonio-cobalt compounds. Among them were the salts of an entirely new base, croceocobalt, in which two nitro-groups were present. In all, five distinct series were studied, their chlorides being represented, in modern notation, by the subjoined formulæ:

Luteocobalt chloride..........	$Co(NH_3)_6Cl_3$.
Roseocobalt chloride..........	$Co(NH_3)_5.H_2O.Cl_3$.
Purpureocobalt chloride.......	$Co(NH_3)_5.Cl.Cl_2$.
Xanthocobalt chloride.........	$Co(NH_3)_5.NO_2.Cl_2$.
Croseocobalt chloride.........	$Co(NH_3)_4(NO_2)_2.Cl$.

Gibbs' formulæ were somewhat different from these, being doubled, and with the water of roseocobalt regarded not as constitutional, but as crystalline. The simpler, halved expressions were established by cryoscopic methods which did not exist when Gibbs conducted his investigations.

The researches upon the platinum metals, published by Gibbs in the years 1861 to 1864, relate mainly to analytical methods. Processes for the solution of iridosmine were carefully studied, and various new separations of the several metals from one another were devised. Incidentally, a number of new compounds were prepared, which, with a few exceptions, Gibbs never fully described. In 1871, however, he published a brief note on the remarkable complex nitrites formed by iridium,* and in 1881 he described a new base, osmyl-ditetramin, $OsO_2.4NH_3$, together with several of its salts. These researches were never pushed very far, and were discontinued for lack of proper facilities. They were, nevertheless, distinct additions to our knowledge of the platinum group.

I have already mentioned the work done by Gibbs and his students in the Laboratory of the Lawrence Scientific School. This covered a wide range, partly in developing and perfecting old analytical methods, partly in devising new ones. There were improvements in gas analysis, especially in the determination of nitrogen, and a great variety of analytical separations. I will not attempt to give a catalogue of these investigations, but will limit myself to a few of the more noteworthy. A new volumetric method for analyzing the salts of heavy metals was worked out, in which a metal such as copper or lead was precipitated as sulphide, the acid being afterwards determined by titration. The estimation of manganese as pyrophosphate was another of these contributions to analysis. But the most important of all was the electrolytic determination of copper, now universally used, which was first published from Gibbs' laboratory. It is true that a German chemist, Luckow, claimed to have used the method much earlier, but so far as I can discover he failed to publish it. Gibbs, therefore, is entitled to full credit for a process which was the progenitor of many others. The entire field of electro-chemical analysis was thrown open by him, and it has been most profitably cultivated.* Gibbs also, during this period of his activity, invented several instrumental devices of great convenience. The ring burner, and the use of porous septa when precipitates are to be heated in gases, are due to him. Furthermore, in coöperation with E. R. Taylor, he devised a glass and sand filter which was the forerunner of the porous cones invented by Munroe when the latter was a student in Gibbs laboratory. That, in turn, preceded the well-known perforated crucibles of Gooch, who was one of Gibbs' assistants. The genealogy of these inventions is perfectly clear.

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* Ber. Deutsch. chem. Ges., 4, 280. Not a separate paper, but part of his correspondence.

We come now to the remarkable series of researches upon the complex inorganic acids, which Gibbs began to publish in 1877, and continued well into the nineties. The ground had already been broken by others; silicotungstates, phosphotungstates, phosphomolybdates, etc., were fairly well known, but they were commonly regarded as exceptional compounds rather than as representatives of a very general class. In his first preliminary communication upon the subject Gibbs indicated the vastness of the field to be explored, and showed that the formation of complex acids was characteristic of tungsten and molybdenum to an extraordinary degree. The phenomena were general, not special; and no limit could be assigned to the possible number of acids which these elements might form.

In his systematic work, following his preliminary announcement, Gibbs first revised the sodium tungstates in order to determine their true composition. Then, after preparing a number of phosphotungstates and phosphomolybdates, he studied the corresponding compounds containing arsenic in place of phosphorus. He next obtained similar vanadium compounds, and also showed that the phosphoric oxide of the first known acids was replaceable by phosphorous and hypophosphorous groups. Later still, he replaced the normal phosphates by pyro- and meta-phosphates, and also prepared complex salts containing arsenious, antimonious, and antimonic radicles. Stanno-phosphotungstates and molybdates, platinotungstates, and complex acids containing mixed groups were discovered, together with analogous compounds of selenium, tellurium, cerium, and uranium. One salt described, a phospho-vanadio-vanadico-tungstate of barium, had the formula

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*Notably by Smith in this country, and Classen in Germany.

$$60\ WO_3.3P_2O_5.V_2O_5.VO_2.18BaO.150H_2O,$$

with a molecular weight of 20066. Compared with this substance the supposed complexity of most organic compounds becomes simplicity itself, and their interpretation seems relatively like child's play. In all, Gibbs described complex salts belonging to more than fifty distinct series, and did his work in a small private laboratory, with only a single assistant. With greater resources at his command, what might he not have accomplished?

In 1898, in his address as retiring president of the American Association for the Advancement of Science, Gibbs summed up his views as to the constitution of the complex acids. His presentation of the subject, however, can hardly be regarded as final. The problems involved are too complicated to be easily solved, and much future investigation is needed in order to determine the true character of these extraordinary substances. Gibbs was a pioneer, breaking pathways into a tangled wilderness; but the ways are now open, and he who wills may follow. Possibly some of the compounds so far obtained were double salts; others may have been isomorphous mixtures; and in some instances phenomena of solid solution perhaps obscured the truth. By physical methods, cryoscopic or ebullioscopic, the molecular weights of the salts must be determined; their ionization needs to be studied, and in such ways their true nature can be ascertained. These methods of research have been mainly developed since the work of Gibbs was done; he therefore cannot be criticised for not employing them. Since his time chemists have come to recognize many compounds as salts containing complex ions, such as, for example, the oxalates, tartrates, etc., of iron, aluminum, chromium, and antimony, with other bases of lower valency. Even many of the silicates are easiest to interpret as salts of alumino-silicic acids, although the physical proof of their nature is difficult to obtain. The constitution of the complex acids is one of the great outstanding problems of inorganic chemistry.

Although he was distinctively an inorganic chemist, Gibbs did not entirely neglect organic chemistry. In 1868 he discussed the constitution of uric acid and its derivatives, and in 1869 he described some products formed by the action of alkaline nitrites upon them. He also produced several memoirs upon optical subjects, such as one upon a normal map of the solar spectrum, and another upon the wave lengths of the elementary spectral lines. Again, he devoted some time to the study of interference phenomena, and discovered a constant, which he called the interferential constant, that was independent of temperature. One of Gibbs' latest papers, published when he was seventy-one years old, related to that extremely difficult subject, the separation of the rare earths—a subject in which he had always taken a deep interest. In this paper he developed a new method for determining the atomic weights of the rare-earth metals, which was based upon analyses of their oxalates. The oxalic acid was determined by titration with permanganate solutions, and the oxides by ignition of the salts. From the ratios between the oxalic acid and the oxides the molecular weights of the latter could be computed without reference to the amount of moisture in the initial substances. This method has since been employed by others, and especially by Brauner, in his work on the atomic weights of cerium and lanthanum. It is worth noting here that Gibbs had previously taken some part in atomic weight determinations. Those of Wing on cerium, and of Lee on cobalt and nickel, were made in Gibbs' laboratory and under his guidance. Furthermore, Gibbs was one of the earliest American chemists, if not the first, to accept the modern or Cannizzaro system of atomic weights, and to use it in his teaching. His mind was never closed to new ideas. It welcomed light from all sources.

Gibbs wrote no books and delivered no popular lectures. He was therefore little known to the public at large, but within scientific circles he received high honors. He was president of the National Academy of Sciences from 1895 to 1900, and he also presided over the American Association for the Advancement of Science in 1897. Honorary membership in the German, English, and American chemical societies, and in the Prussian Academy was conferred upon him, and he received honorary degrees from several universities. His life was that of a devoted scholar, caring most for research, and indifferent to popularity. Sensationalism and self-advertising were most obnoxious to him; indeed, in these respects, no man could have been more fastidious. The approval of his fellows he fully appreciated, but only when it was spontaneous and deserved. It must not be inferred from these remarks that Gibbs was deficient in public spirit, for that would be most untrue. During the Civil War, from 1861 to 1865, he was strongly patriotic, and did much to help the Union side. The Union League Club of New York, organized to bring together the more patriotic citizens of that city, was founded at a meeting in his house, and is today a strong social institution. Gibbs was also active in the Sanitary Commission, an organization modeled upon the work of Florence Nightingale in the Crimea, and the forerunner of the Red Cross Society of today.

Wolcott Gibbs was a man of striking personality, tall, erect, and dignified. As with most men of positive character, he had strong likes and dislikes, but the latter never assumed unworthy form. To his friends he was warmly devoted, and always ready to help them in their work with manifold suggestions. His breadth of mind is indicated by the range of his researches, and his liberality by the way in which he encouraged his students to develop his ideas. More than one important investigation was based upon hints received from him, and was carried out under his supervision, to appear later under another name. Gibbs never absorbed the credit due even in part to others, nor failed to recognize the merits of his assistants in the fullest way. Had he been more selfish, his list of publications would have lengthened, but his sense of justice was most keen, and therefore he held the esteem and confidence of his co-workers. No man, not even among his opponents, for such there were, could ever accuse him of unfairness. He deserved all honor, and his name will live long in the history of that science to which his life was given.

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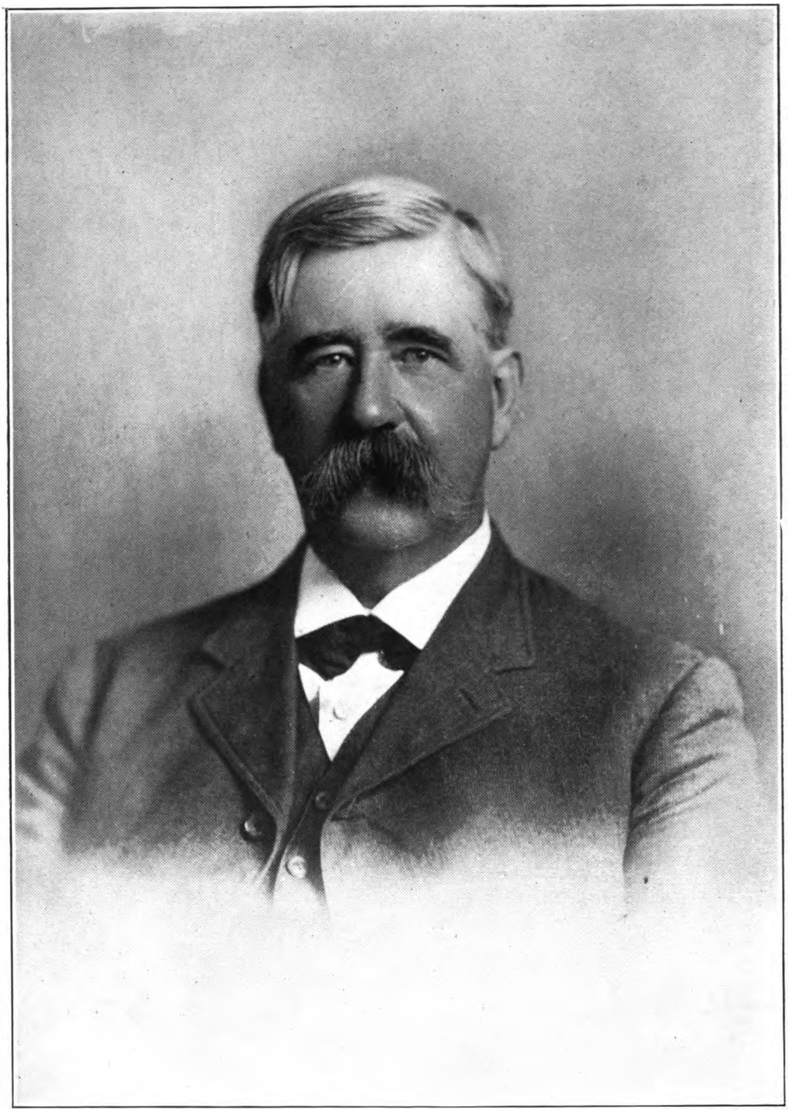

Yours Truly
W. K. Brooks

UNIV. OF MICH.

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WILLIAM KEITH BROOKS.*

ANCESTRY AND FAMILY.

William Keith Brooks, Professor of Zoology in the Johns Hopkins University, was born at Cleveland, Ohio, March 25, 1848, and died at his country home, "Brightside," near Baltimore, November 12, 1908.

Although Professor Brooks used to say jocosely that his known line of descent was too short to be of much interest to a student of phylogeny, it goes back, nevertheless, to some of the earliest settlers of Massachusetts. On his father's side he was descended from Thomas Brooks, who came from England to Boston prior to 1634, and soon thereafter settled in Concord. For five generations preceding the Revolution the Brooks homestead was in Concord. His great grandfather, Joshua Brooks, served in the battle of Concord; his grandfather, Joshua Brooks, was born in Lincoln, Massachusetts, in 1780, whence he removed to Burlington, Vermont; his father, Oliver Allen Brooks, was born in Middlebury, Vermont, in 1814, and moved to Cleveland, Ohio, in 1835, where he became one of the early merchants of that city.

Through his mother he was descended from John Kingsley, who came from England to Dorchester, Massachusetts, about 1638. His maternal grandfather, the Rev. Phineas Kingsley, was born in Rutland, Vermont, in 1788, and moved to Ohio in 1847; his mother, Ellenora Bradbury Kingsley, born June 30, 1817, was married in 1840 to Oliver Allen Brooks, of Cleveland. The parents of Professor Brooks were second cousins, both of his grandmothers having been cousins of the name of Keith, and descended from the Rev. James Keith, who came from Scotland to Boston in 1662, and became the first settled minister of Bridgewater, Massachusetts.

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* In the preparation of this memoir the writer has had the invaluable assistance of Mr. Oliver K. Brooks and Prof. E. A. Andrews. The former has supplied all information available concerning the ancestry and early life of his brother, and he has also furnished certain details concerning his later life and personal traits. Professor Andrews has assisted materially in the compilation of the bibliography, and a free use has been made of his several articles on Professor Brooks.

Although the genealogy of Professor Brooks is thus known for eight generations, the characteristics of his ancestors are not sufficiently well known to justify an attempt to study his heredity. Most of his immediate ancestors in this country were farmers, but his maternal grandfather, the Rev. Phineas Kingsley, was a Congregational clergyman. He had only a common-school education, and had studied theology under a local clergyman, but he was a studious, well-informed man; he had a fund of knowledge about animals and plants, derived from his own observations, rather than from reading, and it is not improbable that his conversation and example may have turned his grandson's attention to the study of living things.*

William Keith Brooks, the subject of this memoir, was the second son of Oliver Allen and Ellenora (Kingsley) Brooks. He had three brothers, all of whom survive him; the oldest, Oliver Kingsley Brooks, born May 21, 1845; the third son, Charles Ernest Brooks, born March 30, 1851; the youngest, Edward Howard Brooks, born November 21, 1854.

Professor Brooks married, on June 13, 1878, Amelia Katherine Schultz, daughter of Edward Thomas Schultz and Susan Rebecca (Martin) Schultz, of Baltimore. To them two children were born, Charles Edward Brooks, August 26, 1879, and Manetta White Brooks, April 21, 1881; the former, after finishing his undergraduate course, took the degree of Ph. D. in mathematics at the Johns Hopkins University, and is now devoting himself to research in that subject; the latter is a graduate of Vassar College, and after the death of her mother in 1901, took charge of her father's home and became his daily companion; in 1909 she married J. Frank Daniel, Bruce Fellow in Biology in the Johns Hopkins University.

Professor Brooks rarely spoke of his ancestry or early life, and for the following illuminating account of his boyhood, which I have taken the liberty of editing and arranging, I am indebted to his brother, Oliver K. Brooks.

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* William L. Kingsley, long-time Treasurer of Yale College, was a cousin of Phineas Kingsley.

EARLY HISTORY OF W. K. BROOKS.

BY OLIVER K. BROOKS.

EARLY DAYS IN CLEVELAND.

"The conditions in which my three brothers and I spent our childhood and youth were almost ideal. Our father lived on lower Euclid avenue, then one of the pleasantest and most agreeable residence sections of the city, now entirely given up to business. We had congenial neighbors, most of whom lived near us for a long time. Many of them had children of about our own ages who were our friends and companions.

"We lived in a large, comfortable, and substantial old frame house with large grounds, especially in the rear, where there was an apple and pear orchard and a hickory tree, reminders of the time when the place was country property, or perhaps part of a farm.

"Near the house was a builders' lumber yard, which was a favorite playground for us, and near by, in another direction, was a convent of Ursuline nuns, with extensive buildings and grounds, separated from the street by a high brick wall. This convent was a place of mystery to us.

"We had an indulgent father and a devoted mother, and an aunt, my mother's sister, who lived with us as one of the family until she married, and until some time after, when her husband, Mr. Warner, bought a house nearly opposite our own. Their house was always like a second home to us.

"My mother's father and mother lived on a small farm some five or six miles south of the city on the Columbus road. He was a retired Congregational clergyman, but he never had a church of his own after he came to Ohio, but used to preach in neighboring towns when he was needed.

"It was a great delight to us to visit our grandfather's farm, and I and my brother William used to spend Saturdays and holidays there. Grandfather used to entertain us with stories of his life in Vermont and of the pioneer days there. He had seen military service in the days preceding the War of 1812.

He had an excellent memory, and was a very good story teller. He taught us to fish, and used to take us on nutting expeditions in the fall.

"Talks with him may have had something to do with turning my brother's thoughts to the study of animated nature. He had in his small library two books—"Thompson's History of Vermont" and the "Philosophy of Natural History," by Smellie—in both of which I know my brother was interested. The first contained an account of the fauna and flora of Vermont, and served my brother as a sort of text-book. I have the book in my possession now, and in it my brother has marked the birds and other creatures which he had found about Cleveland. In some cases he had indicated where the specimens were found.

"My uncle, Mr. Warner, noticed my brother's taste for the study of animals, and encouraged it, and gave him a copy of "Wood's Natural History" as a Christmas present in 1862. While still a schoolboy my brother sent to a sporting paper called "Wilkes' Spirit of the Times," an interesting account of the intelligent conduct of a little dog which belonged to his grandfather. The account, I believe, was headed "Do Animals Reason," and was in the form of a letter to the paper, and was either not signed or only signed with initials. Our uncle discovered it in the paper, and guessed that it was written by my brother, and he "owned up" on being spoken to about it. I think this was his first appearance in print.

"One of our neighbors was the geologist, Prof. J. S. Newberry, afterwards of the School of Mines, Columbia College. He had several sons who were companions and playmates of my brother, and I think they used to go on excursions into the country and collect specimens together. Doctor Newberry had, in a small building near his house, a large collection of fossils and geological specimens, and a knowledge of these may have stimulated my brother to make similar collections. I remember that my brother during his school days read, with a great deal of interest, Hugh Miller's works on Geology, and the works of Doctor Buckland on the same subject, and other books of a similar nature.

"Our mother died after a very brief illness, in June, 1862. My father's mother and sister kept house for him until he married again. His second wife was a widow with a young daughter, who became a member of the family and introduced a new element of interest into our home life.

"The nearby lake, river, and canal were, of course, very attractive to young boys. There was a good bathing beach on the lake shore within walking distance of our house, and we used to go there to bathe during the summer. The river and canal abounded in fresh-water mollusks which were interesting. A part of the river, near where it emptied into the lake, had been cut off by a change of the channel, and was known as the "old river bed." Wild fowl were found there, especially in the spring and fall, and my brother once shot a blue heron there. On one of our trips to the "old river bed" my brother's dog chased some chickens. The owner, an old German, was very angry, or pretended to be, and brought out a shotgun and threatened to shoot the dog. We were thoroughly alarmed, but my brother stooped down without a moment's hesitation and put his arm around his dog and shielded him with his body. He was willing to run the risk of being shot rather than have his pet and companion exposed to danger.

"My brother became interested in aquaria, and had an aquarium in the house and a pond in the yard, stocked with tadpoles, water snails, and small fish. In this pond lived a frog which had learned to come and take flies from his hand. He always had animal pets, which he treated with great kindness; almost always a dog was his companion on his tramps, and he also had pet rabbits, cats, and squirrels. He was very skillful in training animals.

[To his students in after years Professor Brooks occasionally spoke of these early observations and experiments upon animals. In particular he recalled the great flocks of carrier pigeons which at times darkened the sky, and which flew so low after their long southward flight across Lake Erie that they could be struck with poles and clubs as they rose over the bluffs on which Cleveland stands.]

"In imitation, probably, of Professor Newberry's collection, he established a sort of museum in the upper story of the barn back of the house, where he had a collection of shells, fossils, minerals, and geological specimens arranged on shelves, classified and labeled.

"It was probably about this time that he learned to stuff birds, or rather to prepare their skins for preservation. He may have learned to do this from some lectures given by Doctor Kirtland on the subject.

"When he grew old enough to be allowed to do so, he took long tramping expeditions into the neighboring country, sometimes hunting a little, but mostly exploring, observing, and collecting specimens. He formed a friendship with Col. Charles Whittlesey, a geologist and mineralogist, and with him explored and investigated some of the Indian mounds and earthworks in the valley of the Cuyahoga river.

"In his walks and excursions his mind seemed always occupied with problems suggested by what he saw. The commonest objects which most would pass by without a moment's thought set him to thinking and trying to work out explanations of observed features, conditions, and phenomena.

"The first microscope my brother had was made for him by his friend, Mr. Charles F. Brush, the inventor of the Brush electric light. My brother had learned to grind glasses, and devised an ingenious method of making a holder for glass he was grinding. He cut off a piece of broomstick, wrapped paper around it, letting the paper project above the end of the stick, forming a sort of cup or socket. Into this he poured lead, and before the lead had hardened he pressed a marble into it, forming a concavity which served as a socket to hold the glass while being ground.

"Some of the work on the microscope may have been done in the office of Dr. A. Maynard, a retired physician of cultivated and scholarly tastes, who had a fine metal-working lathe which he allowed my brother to use. The Doctor always took an interest in my brother's work and assisted him in many ways. I do not know when my brother first made his acquaintance, but as the Doctor was a friend of my aunt and uncle, Mr. and Mrs. Warner, it was probably at their home that the acquaintance began. The Doctor had a fine library, and encouraged my brother to come to his rooms and make use of his books.

SCHOOL DAYS.

"My brother received his early education at the public schools of Cleveland. The schools he attended were all within walking distance of our home. He first attended the "Prospect" School, primary and intermediate, quite near home. One of his teachers, a lady, says of him: "I remember him as possessing a most cheerful and loving disposition, and being very bright and quick to learn." From that school he was advanced to the "Eagle" grammar school. The principal was a Mr. Perkins, who was assisted by his wife. They remember him as a good boy of quiet and gentle manners, who never gave them any trouble, but do not recall anything to indicate the ability he afterwards developed. One of his schoolmates there was Prof. Theodore B. Comstock, now of Los Angeles, California, who wrote me as follows:

> William (we called him Will) was fond of animals and was of an investigating turn of mind, as a boy. He knew more of Nature than his associates and took keen interest in what he observed. Reptiles and venomous insects were his pets. His will was strong, but not aggressive. An incident in my experience with him will illustrate this: One day I had teased him, and on our way home he quietly said, "Don't you say that again." I ran off to a safe distance and mocked him. He started for me with doubled fist, showing no emotion, but coming towards me with a steady walk. I dodged him for awhile, and then concluded he had given up the chase, as he did not appear angry and kept up his steady walk. Finally, I came over to him unconcernedly. He walked calmly by my side, raised his arm, and struck me on my shoulder. That was all, but my shoulder was very sore for many days afterwards. Aside from his attachment to animals, I remember nothing in his early youth which could be regarded as clearly indicating his later career.

"He was never a plodding student, his quickness of mind enabling him to grasp a subject rapidly, and when he had once done so he lost interest in its details. From the grammar school he went, in 1863, to the Central High School, which was then quite near our home. The principal there was Dr. Theodore Sterling, afterwards president of Kenyon College, and he was assisted by Professor Norton, now Professor of Chemistry at Ohio State University, at Columbus. Both remember him well. Doctor Sterling wrote me as follows in regard to him:

> I remember he was fond of taking walks in the fields and woods, and collecting and putting in his pocket whatever interested him, whether shells or pebbles or plants or bugs. Sometimes when I met him he would empty his pockets, showing me what he had found and get what information he could from me about whatever excited his interest. This seemed to indicate that his love for natural history was very early developed.

"Professor Norton wrote:

> I do not think that he studied chemistry or Virgil under me, but in all likelihood he was under me in some of his early studies, botany and natural philosophy for instance. As I call him to mind, he was a quiet, studious boy, rather reserved in his manner, and not much given to the ordinary boyhood jokes and games.
>
> The last time I met him, so far as I can recollect, he was engaged in a summer school of natural philosophy in the upper floor of the High School, together with Prof. A. H. Tuttle, now of the University of Virginia. I was much struck with the mastery he exhibited in his school and surprised at his early maturity.

"He went by the name of 'Mummy' among his schoolmates, probably because of his silent habits. At the high school his liking for and ability in mathematics and natural science was notable, and is remembered by his teachers and fellow-students, one of whom was Dr. J. H. Lowman. He and Doctor Lowman took private lessons in Greek from Professor Rueger, who was a teacher of German in the high school, and thereafter this subject had a charm for him second only to that of mathematics and natural science.

"Doctor Lowman remembers his early work with the microscope, and being shown the teeth of a snail and the epithelial cells of tissues, and thinks he worked with the microscope in Doctor Maynard's office.

"My mother had a liking for the fine arts, and had some little native ability in drawing and coloring, although she had had no training, and very little opportunity to cultivate this natural gift. When my brother began to use the microscope, he asked me to show him how to draw the objects he was studying. I gave him a few instructions, but almost from the start he grasped the idea, and soon became very skilful in drawing with the pen. All he seemed to need was a few suggestions to start him right, and he went on without assistance and soon taught himself to make beautiful and elaborate drawings with the pen.

"He had a congenital defect of the heart which prevented his taking any active part in sports at school, but he was fond of playing checkers, and was very expert indeed at the game. A little later—perhaps he was sixteen years old at the time—he took up chess, and gave it serious thought and study. In later life he was an expert whist player, and was rarely, if ever, beaten at the game.

"He organized a society of some of his schoolmates while at the high school, and later one which met in a room in a downtown business block. This society was called "Magnus Pax," and met to read selections and discuss various subjects. There were probably not more than a dozen members, all told.

"He did not graduate at the high school, but left at the end of the third, or junior, year, in 1866, to enter Hobart College.

"I think my father's second wife felt little sympathy with my brother's desire to devote his life to study and research. She may have influenced my father to some degree, and I have no doubt my father was deeply disappointed in not being able to induce my brother to apply himself earnestly to business.

"He may have had a feeling that if he gave his sons a common school education sufficient to fit them to make their way in business, that was enough, and after that they ought to get to work and take care of themselves. He may have looked on a college education as a luxury that might render one unfit for a business career.

"Because of this feeling it was hard for him to sympathize with or encourage my brother's desire to devote himself to a life of study and research. He could not comprehend how a living could be made in that way, and he felt his sons must early find a way to support themselves. While he was ready and willing to assist them in getting a start in life, he probably felt unable to do more than this, and that to do more for one in supporting him while at college might be unjust to the others, or might limit his ability to help them in turn. Still, when he found my brother bent on having a college education, he gave him all the assistance he thought he could afford, and when he achieved success and had recognition, he was very proud of him.

"An old friend of Doctor Maynard, mentioned above, told me the following incident:

"The Doctor told him that my father at one time came to him in a good deal of perplexity, to ask his advice about Will, who had then been taken into his store, but who showed no interest in business and no inclination for it, but, on the contrary, seemed to have his mind occupied with other matters which had no relation to business, and of which my father could not see the use. The Doctor had seen a good deal of Will, and Will had talked with him pretty freely about the subjects and studies which attracted him, and he told my father he thought it was better to let Will follow his evident inclination for a life of study and research, believing he would never adapt himself to a business life, and would only be made unhappy by being confined to an uncongenial occupation, but that he was in no danger of becoming a mere idle loafer, and, on the contrary, had ability which would become evident if he were allowed to follow his inclinations, and that if so allowed the boy would show he had good stuff in him and a mind above the ordinary, and would probably succeed."

COLLEGE AND UNIVERSITY CAREER.

He entered Hobart College, Geneva, New York, in the fall of 1866, and left at the completion of his sophomore year. His cousin, the Rev. Wm. J. Cleveland, of Bostonia, California, writes: "We were at Hobart College together for some time, and it may have been through my being there and urging him to come that he began his higher studies there." He remembers that he was liked by the best element among his fellow-students for his cheerful, gentlemanly bearing, coupled with a quiet but telling wit. He was not a plodding book slave, but quick of intellect and wide-awake, and he found his recreation more in mental than in physical activity. His son, Dr. Charles E. Brooks, informs me that while his father was a freshman at Hobart he won the White Essay Prize, never before taken by a freshman. That he had already begun to read and appreciate philosophy is shown by the fact that his volume on "The foundations of zoology," published in 1898, is dedicated "To Hobart College, where I learned to study and, I hope, to profit by, but not to blindly follow, the writings of that great thinker on the principles of science, George Berkeley."

Leaving Hobart at the end of his sophomore year, he entered the junior class at Williams College in the fall of 1868. Concerning his life at Williams, Mr. T. H. Brooks, of Cleveland, a lifelong friend, but not a relative, writes:

> I look back over half a century of acquaintance with Prof. William K. Brooks, commencing, of course, at a very early period in our lives. We played together, went to the public school here together, and later were classmates at Williams College, and were both graduated from there in 1870. I never knew him otherwise than kind, gentle, thoughtful, and studious; not demonstrative in his friendships, but thoroughly loyal and sincere. He cared nothing for marks or prizes in college, was very liable to burn the midnight oil over some subject that specially appealed to him, and then "cut" prayers and early recitations the next morning. He never put himself forward to answer the questions of the class room, but when called upon always gave a good account of himself. College boys, so far as my experience goes, take the problems of calculus without question and almost without understanding, but he grasped and was delighted with every proposition, and to the utter amazement of his professors and classmates, discovered a mistake in the text-book used. He was generally acknowledged to have been the most brilliant student in mathematics Williams had ever seen."

His love of the natural sciences was fostered by the Lyceum of Natural History at Williams, an active organization which at one time sent a natural history expedition across South America, and by Sanborn Tenny, botanist and zoologist, under whom he studied. But the history of his whole life indicates that he was not led into the study of zoology by teachers or environment. We may apply to him with especial force the following sentiment from his address before the Seventh International Zoological Congress (p. 34): "Most of us have, no doubt, been drawn to our specialty by the natural bent of our minds, rather than by deliberate choice. The zoologist who best deserves the name is one whose natural bent has been too strong for him, so that he has studied zoology because he could not help it." Prof. E. A. Birge, of the University of Wisconsin, was a freshman at Williams when Brooks was a senior. He remembers that Brooks had a microscope, a rare thing in those days, and that with it he showed many interesting things to his fellow-students, who frequented his room, evenings. On one occasion he undertook to demonstrate a cross-section of a hair, and after much difficulty in trying to cut a free-hand section, he lathered and shaved a portion of his face, and then engaged the students in other things, while he waited a half hour for the hair to grow before he shaved again.

Prof. S. F. Clarke, of Williams College, one of his first students at the Johns Hopkins University, said of him in an obituary notice in the Williams Record:

> His mind was markedly of the philosophical type which appeared even in his college days, when he was known among his classmates as "the philosopher." I remember his saying that there were two things in his college course which were of special interest to him, and which also in the retrospect gave him the most satisfaction: one was solving the problems of Euclid; the other was the study of philosophy under Mark Hopkins.

In 1870 he received the degree of Bachelor of Arts and was elected to the honor society, Phi Beta Kappa. It is probable that at this time he had decided to follow a career of teaching and investigation, but it seems likely that he doubted whether he could find an opportunity to teach natural history, for in after years he said that he was in doubt when he left Williams whether he should teach mathematics, Greek, or biology. However proficient he may have been in the two former, there can be no doubt that by nature, early training, and inclination he was especially fitted for the career which he later entered. As indicating the manner in which he was "finding himself" at this time, the following extract from a letter of his cousin, the Rev. William J. Cleveland, is of interest:

> On another occasion, I think it was in 1869 or '70, after I had graduated, he visited me at Orange, N. J., and was full of the idea of teaching. He had with him a big lot of specimens of one kind and another, and his ambition was to try the experiment of giving public lectures. Enlisting me as assistant in a business way in this enterprise, a hall was engaged and announcements made in a small town "up the road" from Orange. I do not recall whether it was Milburn or Chatham, but at one of them he delivered what, no doubt, was his first public lecture. There was not a big crowd, but my recollection is that there was a very respectable and interested audience, and that all passed off nicely. He was in no sense oratorical or florid, but he went straight to his subject and on with it to the end, relying solely upon the interest of the subject itself, which was so great to him, to hold the attention of the audience.

> I have tried hard, but with very meager results, to recall the topic and subject-matter of the lecture. I feel quite sure now, however, that the subject was "Mollusks," but I remember nothing of what he said except that he spent considerable time, as it seemed to me at the time, in explaining to the audience what Mollusca were.
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> I believe his only object then was to try the experiment of giving a public lecture and to find out how he stood the ordeal. For that reason, perhaps, he chose a (then) small and out of the way place, and the whole venture was managed in the most quiet and unpretentious way. As I remember, no hand-bills or other printing of advertisements was resorted to to draw a crowd. To give a lecture before a mixed audience in some public place and get enough out of it financially to fairly meet expenses, was all he aimed at. That experience, no doubt, had some influence in convincing him that the class room rather than the platform was the place where he could do his most efficient work.

Following his graduation from college, young Brooks spent the year 1870-71 in business with his father, who was an importer and wholesale dealer in crockery, china, and glassware. Prof. E. A. Andrews, in his biographical sketch (Johns Hopkins University Circular, No. 212, January, 1909), says that during this year "he exhibited characteristic interest in the solution of problems and distaste for such mechanical drudgery as had only practical and not theoretical ends in view, by the invention of a calculating machine to lessen the amount of unprofitable manual labor." There is evidence that he continued his reading and study during this year, as much as his other duties would permit, and he and other young men continued to meet at his club for talks and discussions.

In the fall of 1871 he entered definitely upon his career as a teacher. He was employed as one of the masters at De Veaux College, Niagara Falls, New York, where he remained for two years. His ability to win the confidence, respect, and affection of his students was notable even at this early stage in his career. He had a way of not only interesting his scholars, but also of attaching them to him personally. The Hon. Herbert P. Bissell, of Buffalo, New York, who was a student at De Veaux College at that time, has written the following concerning Professor Brooks:

> I have consulted with several old De Veaux boys, but none of them could add very much to my own knowledge of Professor Brooks. We all remember him as a man devoted to scientific research and constantly

studying the geology and the flora and fauna along the Niagara River. I recall the interest he would take in any geological specimens that we would find underneath the high bank of the Niagara River. He would give us his opinion promptly as to the geological age to which the specimen belonged, etc. His work at De Veaux College was most satisfactory; he was an excellent and interesting teacher and, as I have intimated, devotedly attached to scientific investigation.

He remained at De Veaux College for two years, and then entered upon the professional course of training in zoology for which he had been planning and preparing. At Harvard, Louis Agassiz was at the climax of his wonderful career, and many young men, who afterward became leaders in biology, went there to study under this great master. In particular in the summer of 1873 the establishment of Agassiz's new seaside laboratory on the island of Penikese, in Buzzards Bay, attracted wide attention. This new departure, the first of the summer schools, was projected by Agassiz in the preceding winter; the island and a fund for the establishment of the school were given by Mr. John Anderson, of New York, in March, and the large buildings were hastily constructed, and were scarcely ready for occupancy when the school opened early in July. Between fifty and sixty teachers and investigators were present, and among these was Brooks. From that time until his death he remained a student of marine life. The sea, with its teeming multitudes of living things, always had a particular charm for him, not merely because of the interest and variety of its forms of life, but also because it was probably the scene of the earliest acts in the drama of evolution.

From this time forward throughout almost his whole life he spent a part, at least, of every summer at the shore. In 1874 he was again at Penikese at the last session of that famous but short-lived laboratory. In 1875 he was with Alexander Agassiz at his private laboratory in Newport, Rhode Island, working on the embryology of Salpa, and tutoring one of Mr. Agassiz's sons. In 1878 began the sessions of the Chesapeake Zoological Laboratory, which he founded and directed for many years. In the summers of 1888 and 1889 he was at the U. S. Fish Commission Laboratory at Woods Hole, Massachusetts, and in later years he was frequently at the Commission's Laboratory at Beaufort, North Carolina. He was a trustee of the Marine Biological Laboratory almost from its foundation until his death. In the summers of 1905 and 1906 he was at the marine laboratory of the Carnegie Institution of Washington, at Tortugas, Florida. His scientific life was thus closely identified with marine laboratories, beginning with the earliest of these at Penikese, and ending with the latest at Tortugas.

In the fall of 1873 he entered the graduate school of Harvard University, where he continued two years, receiving the degree of Doctor of Philosophy in 1875. At Cambridge he came to know several zoologists whose work and influence helped in some measure to shape his career. First among these must be named Louis Agassiz, of whom Brooks occasionally spoke in later life and whose influence upon him was profound though brief. Agassiz died in December, 1873, and Brooks' association with him was thus limited to the summer session at Penikese and the autumn term at Harvard. Among others whose influence he felt must be mentioned Alexander Agassiz, McCrady, and Hyatt.

While at Harvard Brooks and some other young zoologists lived in an old wooden building known as Zoological Hall, which stood where the Peabody Museum now stands. Professor Birge, who lived in the same building and thus saw Brooks frequently, remembers that he lived very simply and was apparently supporting himself, and that his usual carelessness of dress was emphasized by the fact that he mended his torn clothes with white string. His life was studious and generally solitary, save for the companionship of a great St. Bernard dog, "Tige," who always walked with him when he went out and who occupied most of his bed at night. "I hardly think," says Professor Birge, "that any of his ideals were shaped by the men with whom he worked. He read much and thought for himelf. One day he brought me a new copy of Darwin's Origin of Species, and when I asked him what this meant, he told me that he had borrowed mine one day when I was out, and, having kept it a good while, had written so many notes in it that he preferred to buy me a new copy rather than give the old one back."

In the summer of 1875, after his graduation from Harvard and before his visit to Mr. Agassiz's laboratory at Newport, in August and September of that year, he was instrumental in organizing a laboratory for instruction in Biology in Cleveland. As no fees were charged for this course it seems probable that his purpose was to gain experience in teaching, as well as the purely disinterested aim of establishing an inland Penikese for the instruction of teachers and students of natural history. In his address at the dedication of the new biological laboratory of Western Reserve University, in 1899, he described that enterprise in the following words:

> It was my good fortune to have a share in one of the first attempts to organize laboratory instruction in Cleveland, and I hope you will pardon me if, on this occasion, my mind runs back to this old undertaking. In 1875 three young men who had begun to train themselves as naturalists, came together for their summer vacation, at their homes in Cleveland. They were Theodore B. Comstock, afterwards President of the University of Arizona; Albert H. Tuttle, now Professor of Biology in the University of Virginia, and myself. We were filled with enthusiasm for our work, and, like all earnest students from Chaucer's day to this, as glad to teach as to learn, and we determined to organize a summer class for laboratory instruction in zoology and botany. Money for our expenses was liberally supplied by R. K. Winslow, Leonard Case, and other citizens; the authorities granted us the use of the old high-school building on Euclid avenue near Erie street, and we were soon able to issue notices of our undertaking, and invitations to all who wished to join the class, asking them to do so without the payment of any fee. Some twenty-five were soon enrolled, most of them teachers, some from a distance, and work was begun with a class which shared all the earnestness and enthusiasm of their instructors. We had daily lectures or demonstrations, followed by four or five hours of work in the laboratory, while two afternoons in each week were given to excursions to Rocky River, Cuyahoga Falls, and other places favorable for the out-of-door study of nature. As a small steamboat had been placed at our service, we made two excursions upon the lake, and thus gave to the class an opportunity to learn the use of the naturalist's dredge for collecting the animals of the bottom. Our work was in part the study of the animals and plants which we obtained on these expeditions, and we also made use of a supply of marine animals which had been gathered for the purpose at the seashore.

This account is interesting not merely as a bit of local history, but rather because it reveals thus early in his career his love of teaching and his methods of instruction; the latter, we may be sure, largely influenced by his experience at Penikese.

During the year 1875-76 Brooks was assistant in the museum of the Boston Society of Natural History. This was practically his only experience in museum work. He was not a museum man, being one of the first zoologists in this country to demonstrate in practice that the museum is distinctly inferior to the laboratory as a means of teaching and research. Apart from a small teaching collection he undertook to establish no museum at the Johns Hopkins University, and such collections as he had were for use rather than for exhibition. If a student needed for the sake of his research to dissect a museum specimen, he might feel certain that Doctor Brooks would offer no objection. He appeared to be wholly lacking in that reverence for specimens as such, which the typical museum man is supposed to have. Some of his early students who had been trained in the museum methods then prevalent at some of our oldest and largest universities have confessed that 'when they went dredging with Brooks it made their hair stand on end to see the way in which he chucked material overboard.' With him research was the all-important thing, to which collecting and collections were always subordinate. The writer remembers that on one occasion he brought a distinguished medical man into the students' laboratory in Baltimore, and after showing him a series of sections of a larval Amblystoma, said to him: "Here is a little piece of glass which you can carry in your vest pocket, and which is worth more to one who wishes a knowledge of anatomy than a whole museum full of specimens."

On the founding of the Johns Hopkins University in 1876 Brooks applied for and obtained one of their twenty famous fellowships, which have done so much to change the character of university work and ideals in this country. Before he entered upon his fellowship his abilities as a teacher were recognized and he was appointed associate in biology. In 1883 he was appointed associate professor of morphology, and in 1889 professor in that subject. On the retirement of Prof. H. Newell Martin from the headship of the biological department in 1894, Professor Brooks became head of the department and continued in that position until his death. His active scientific life was therefore coextensive with that of the Johns Hopkins University, and his love of the biological department, and his loyalty to his university were always evident.

CHARACTERISTICS AS TEACHER AND INVESTIGATOR.

Although his publications were numerous and important, I think that his influence was greatest and most far-reaching in his work as a teacher and scientific director. To few zoologists, perhaps to no other in the history of this country, has it been given to direct the work and shape the scientific ideals of so large and influential a body of young men. Among those who took their doctor's degrees under him are more than a score of the leading zoologists of this country, while many other distinguished scholars of this and foreign lands were his pupils.

As a teacher, Professor Brooks was characterized by his breadth of view and his interesting and illuminating style, rather than by his accuracy in details. Like all great teachers, he knew that the primary purpose of teaching is inspiration and illumination, and that information is only of secondary importance. A candidate for the doctor's degree expressed to Professor Brooks, on the morning after his major examination, his mortification that he had blundered in answering one of the questions. With apparent seriousness Brooks said: "Your mistake is a serious one, for it makes you responsible for misinforming my whole class on that subject; I used your answer in my lecture this morning."

His lectures were often vivid and picturesque, as well as clear and logical; and this, joined with his habit of taking little for granted on the part of his hearers and of dealing with the broader and more general phases of a subject, made his lectures interesting not only to biologists, but also to those having no special knowledge of the subject. He invariably lectured without notes, and yet his lectures were so orderly and logical that they bespoke the logical character of his mind. Professor Howell in his memorial address (Johns Hopkins University Circular, No. 212, January, 1909) said, with regard to this, that "when it was known that Brooks was to give a paper before the scientific association of the university it was a custom for men in all the graduate departments to attend the meeting, so much did they appreciate the charm and clearness with which he could present the problems of his subject." I well remember the first time I saw and heard him; it was on the occasion of the annual opening of the graduate school in the fall of 1888. His appearance was neither impressive nor prepossessing, but when he began to speak the closest attention was paid to him. In fascinating terms he described the beauties of the Bahama Islands, with their cocoanut palms and coral reefs; and I shall never forget the enthusiasm and the calm but almost dramatic manner with which he described the finding of the eggs of Gonodactylus in the twilight of his first day in the Bahamas. Equally vivid are the memories in the minds of all his students of his description of the way in which a starfish eats an oyster; of the comparison of a starfish with a sea urchin; of the structure and movements of a jelly fish; of the structure of a squid (in which his own body represented the visceral mass and his coat the mantle); of Salpa, "a barrel with muscular hoops," or Pyrosoma, which at night looked like "a redhot cannon ball." Most delightful, too, were his references to the history of zoological discovery, as, for example, Aristotle's knowledge of the relationships between the various members of a colony of bees, or Chamisso's discovery of the supposed alternation of generations in Salpa.

His blackboard drawings added very much to the interest and value of his lectures; with a firm, even hand he would sketch the form he was describing, and he rarely needed any other eraser than his forefinger. He had learned, early in life, to draw on the blackboard with both hands, by observing the work of Prof. E. S. Morse, while lecturing in Cleveland. He was really an artist of considerable ability and his published drawings were made with much care; in general, they were not only accurate, but also artistic. He was a great believer in pen and ink drawings, and the time and care which he devoted to putting in round and equidistant stipples seemed excessive, until one learned that these were times of reflection with him. His fondness for innovation was shown by his adoption, at one time, of a method of drawing with lithographic pencils on paper, which drawings were then transferred directly from the paper to the stone. In later years he made much use of sepia washes, and he had all his students using them. He expected all his students to learn to draw; to some of them he would say time and time again, "You'd better learn to draw," apparently unmindful of the fact that he had given this advice before, and that they were trying to learn as rapidly as possible; and sometimes, when shown a drawing of which the maker was rather proud, his only comment would be, "You can't do anything well without patience."

He loved to work with simple apparatus, and his technique was never complicated. He never mistook paraphernalia for science, and he went directly to the end he sought. He had a great fondness for primitive methods, and used to advise his students to learn to cut free-hand sections, and to use some of the oldest methods of staining and imbedding. At one time he had some of his students repeating ancient history in trying to imbed tissues in soap, and to more than one who asked him for advice about staining microscopical preparations he recommended Beale's Carmine; the results were always unsatisfactory, but in the meantime the student had learned something about the historical development of staining methods, and, best of all, had also learned to rely upon himself rather than upon Doctor Brooks. One such student, after laboring for some weeks with Beale's Carmine, saw Doctor Brooks and told him that he could not get satisfactory results. After waiting in vain for some response, he ventured to ask whether Doctor Brooks had ever used the method. Yes, he had. "What did you think of it?" "'Twasn't worth a damn." Not infrequently, when students asked him to suggest some topic for research work, he would recommend some wholly impractical thing, such as the study of siphonophores at Woods Hole or the study of Amphioxus at Beaufort; and such students were left to find their own problem and to work out their own salvation.

Although he would present a subject in his lectures in the clearest and most entertaining manner, he rarely, if ever, attempted to smooth the path of the investigator; the latter was to a very large extent thrown upon his own resources. He believed so thoroughly in the law of natural selection, as he once said, that he thought it was best for a student to find out for himself, as soon as possible, whether he was fitted for independent investigation or not, and by this rigid discipline the unfit were weeded out from the fit. This was certainly no school for weaklings, but it afforded magnificent training for those who had ability and determination. For those who endured this ordeal he maintained the warmest regard, and his interest and pride in the work of his students was as marked as it was stimulating.

Throughout the greater part of his life he did most of his research work at night; even the preparation and study of microscopical objects were frequently done by lamplight. He was quite proud of a little device of his by means of which he could imbed objects in paraffin by the heat of his student lamp, which served to illuminate his microscope. It was his custom, after his day's work at the university, to spend the evening with his family, frequently in reading aloud or in playing cards, and then, after all others had retired, he began his work. With his feet wrapped up in blankets to keep them warm he would write, or use his microscope, far into the night. In his work at the shore he would work all day, or all night, as the need might require or his inclination prompt. In his last years night work was no longer possible for him, and he turned to music for recreation, having discovered almost by accident that he had a great fondness for music, and that this liking could be gratified by means of an automatic piano. The last time I saw him we sat up until after midnight playing compositions by great musicians.

In spite of the fact that he was, during the course of his life, interested in many things, he was rarely interested in more than one thing at a time; and this sometimes led to an apparent lack of sympathy with the work of some of his students which was more apparent than real. Occasionally, when he was appealed to for some explanation of some published statement of his, he would say, "I have forgotten all about that now." Often when asked a question, he would say, "I don't know," when he knew better than anyone, although, at the time, the subject was out of his mind. To one of his students who was at work upon a cytological problem, he mildly protested that such work was not morphology; and to one who offered him a thesis on cell-lineage, he remarked, "This university has accepted theses on counting words; I suppose it might accept one on counting cells."

But though he sometimes disagreed with the conclusions of his students, he never attempted to dictate to them. They were treated as absolutely free and independent investigators, and he usually assumed no responsibility for their work or results.

He lived with his students on terms of comradeship. Indeed, between himself and them there existed a real but undemonstrative affection, which was shown on his part, not merely by solicitude for their safety when they were in danger, but by many little kindnesses at the laboratory and in his home. In particular he used to refer with pride and sorrow to those of his students who had died: Rice, Bruce, Humphrey, and Conant. On one of my visits to Baltimore he led me without a word to the tablet which had been placed on the wall of the laboratory in memory of Humphrey and Conant, both of whom lost their lives of yellow fever on their expedition to Jamaica in 1897. We both stood and silently read the tablet, and then as we turned away he said, simply but with emotion, "I thought you would like it." When once relations of comradeship had been established with his students, neither time nor separation changed these relations, and they never needed to be renewed. When attending the International Zoological Congress in Boston, he saw in the hotel lobby a former student whom he had not seen for nine years. He spent no time in renewing acquaintance, but went up to him, as if there had been no break in their associations, and said, "Do you know where I can get a shoestring?" There was a sort of helplessness or lack of worldly wisdom on his part which made his students feel responsible for him, and which increased their affection for him. His interest in his former students was genuine and hearty, though he rarely expressed it to the person concerned. He did not lose his critical judgment in his affection for his students, though he often showed that he was proud of their accomplishments. "One of the joys of a teacher," he once said, "is to see his students surpass him." On the other hand, his students delighted to honor him; and on the occasion of his promotion to a full professorship, on his fiftieth birthday, at the twenty-fifth anniversary of the founding of the Johns Hopkins University, and at the International Zoological Congress in Boston, they showed him how deep a place he held in their affections. On December 31, 1908, sixty of his former students met at a dinner in Baltimore to pay honor to his memory, and the occasion was one of delightful reminiscence and of grateful recognition of indebtedness to him.

THE CHESAPEAKE ZOOLOGICAL LABORATORY.

In connection with his work as teacher and director must be mentioned the establishment by him of the Chesapeake Zoological Laboratory in 1878. The great influence which his experience at Penikese had upon him has already been mentioned. To a large extent the direction and character of his research work was determined by this experience, and its influence was apparent in all his teaching as well as in his research. We have seen that it led him to organize a second "Penikese" at Cleveland in the summer of 1875, and one of his first acts at the Johns Hopkins University was the organization of the Chesapeake Zoological Laboratory. The stimulating influence which this laboratory had upon the research work of Doctor Brooks is shown by his bibliography, where it may be seen that after the first session of that laboratory his annual output of work was increased at least fourfold. And the importance of the laboratory in the development of the biological department of the Johns Hopkins University and in the general advance of zoology in America may be estimated from the large number of students who worked at the laboratory and the large number of papers which they published. Doctor Brooks expected all of his graduate students to spend a season or more at this laboratory. He rightly estimated this as the most valuable experience a student of zoology could have, for in this way the student became acquainted with animals under natural conditions; he had opportunities of becoming a broadly trained naturalist, and he could find his own problems for work and become an independent investigator.

The Chesapeake Laboratory, unlike the one at Penikese, was not limited to one place; it consisted neither of buildings nor equipment, but of men and ideas. For the first few years of its existence it was located at several different points on Chesapeake Bay; afterwards it was located at Beaufort, North Carolina; then at different places in the Bahama Islands, and finally in Jamaica. In the various expeditions of Brooks and his students to these different places they made not only a thorough biological survey of each region, but they did work of most fundamental and far-reaching importance on the various groups of animals found. Out of these expeditions has grown the beautiful and permanent station of the U. S. Fisheries Bureau at Beaufort, North Carolina, in which Brooks took great interest and pride. It was on these expeditions that his students came to know him most intimately and affectionately. In the memory of each of them is fixed some scene of his enthusiasm over the discovery of a rare specimen or of an unknown stage in some life history; his long vigils full of exciting discoveries; his quiet talks on nature and philosophy, after the day's work was done.

The Chesapeake Zoological Laboratory occupied so large a place in the life and work of Professor Brooks that it seems desirable to reproduce here, in his own words, a more detailed account of the aims and history of that laboratory during its first nine years. The following is taken from a report by Professor Brooks on "The Zoological Work of the Johns Hopkins University, 1878-86," published in the Johns Hopkins University Circulars, Vol. 6, No. 54:

> In natural science the policy of the University is to promote the study of life, rather than to accumulate specimens: and since natural laws are best studied in their simplest manifestations, much attention has been given to the investigation of the simpler forms of life, with confidence that this will ultimately contribute to a clearer insight into all vital phenomena.
>
> The oldest forms of life are marine: every great group of animals is represented in the ocean, while many important and instructive groups have no terrestrial representatives; omitting the insects, more than four-fifths of the known species of animals are marine, and the total amount

of animal life in the ocean is incomparably greater than that upon the land. In a word, the ocean is now, as it has been at all stages in the earth's history, the home of life; and it is there, and there only, that we find the living representatives of the oldest fossils, and are thus enabled to study the continuous history of life from its simplest to its most complex manifestations.

On the sand flats at the mouth of the Chesapeake Bay, we find, living side by side, animals like Lingula, Amphioxus, Limulus and Balanoglossus, which are the representatives of some of the oldest and most primitive types of animal life; and all attempts to trace out the natural relationships of any group of animals, lead us at once to forms which are found only in the ocean.

The animals which have contributed most extensively to the formation of the earth's crust, the corals and foraminifera and radiolarians, abound in the ocean today, and it is only by studying their life, by observations at the seashore, that we can understand and interpret their geological influence.

Nearly every one of the great generalizations of morphology is based upon the study of marine animals, and most of the problems which are now awaiting a solution must be answered in the same way.

For these reasons our chief aim in zoology and animal morphology has been to provide means for research upon the marine animals of the Atlantic coast, and for nine years, successive parties, composed of instructors, fellows and students in this department, together with instructors and advanced students from other institutions have spent at the seashore all the months in which marine work is practicable. Their time and energy have been devoted to research rather than to the preservation of collections, and the wisdom of this course can be estimated by examination of the accompanying list of publications; all of which are based, either in part or entirely, upon researches which we have carried on at the seashore.

The wisdom of our policy is well illustrated by the fact that the leading naturalist of America, himself the head of one of the largest scientific collections in the world, says in his annual report for 1884,* that the expenses of an immense natural-history collection are so great that it would be far cheaper, with the present facilities and the cost of travel, to supply the student with the necessary funds for valuable researches, than to go on for years spending in salaries of curators and the care of collections, sums of money which, if spent in a different manner, in promoting original investigation in the field or in the laboratory and in providing means for the publication of such original researches, would do far more towards the promotion of natural history than our past methods of spending our resources.

This fact has become widely recognized during the last ten years, as is shown by the establishment of marine laboratories by several of the

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* Report of the Museum of Comparative Zoology, Cambridge, Mass.

European institutions of learning; and in the summers of 1883 and 1884 we had with us at our laboratory a young English naturalist (Wm. Bateson) who had been provided by the Royal Society of London with funds for his researches, the results of which have recently been published in England.

The Johns Hopkins University was among the first to recognize and act upon this new departure in zoology, and our little marine station is almost as old as the great Naples laboratory. Briefly stated its history is as follows:

In 1878 a small appropriation was made to enable a party of biologists from the University to spend a few weeks at the seashore in the study of marine zoology. Through the influence of Maj. Gen. Q. A. Gillmore, the Secretary of War permitted us to occupy the vacant building at Fort Wool. Prof. Spencer F. Baird also exerted his influence with the Secretary of War in our behalf, and aided us in many other ways; furnishing us with dredging apparatus and with three small row-boats. The scientific results of our season's work were printed in an illustrated volume, the cost of publishing which was borne by the following citizens of Baltimore: Samuel M. Shoemaker, John W. Garrett, John W. McCoy, Enoch Pratt, P. R. Uhler, T. B. Ferguson, Dr. Geo. Reuling, President Gilman, Professor Martin and others.

In 1879 the appropriation for the maintenance of the laboratory was renewed, and in order to present an opportunity for studying the oyster beds of Maryland, the laboratory was opened in three of the barges of the Maryland Fish Commission at Crisfield, Maryland, a point which proved to be very unfavorable. Maj. T. B. Ferguson, the State Fish Commissioner, not only provided the barges for our accommodation, but he also fitted the steam yacht *Lookout* with dredging apparatus, and rendered us valuable help in dredging and collecting. Through his influence a small steam launch was also detailed from the U. S. Navy for our use.

The next year the Trustees of the University voted to continue the laboratory for three years more, 1880–1–2, and they provided a liberal annual appropriation of $1,000 for current expenses, which was renewed annually in 1883–4–5–6, and was expended in rent, wages, fuel, laboratory supplies, repairs, etc. They also appropriated the sum of $4,500 for permanent outfit, and most of this was used in the purchase of two boats; a Herreshoff steam launch twenty-seven feet long and eight feet beam, and a center-board sloop forty-seven feet long and fourteen feet beam.

After an examination of all the available localities the town of Beaufort, N. C., about four hundred miles south of Baltimore, was selected as the site for the laboratory, and a vacant house, suitable for the accommodation of a small party, was found and rented as a laboratory and lodgings for the party, and it has been occupied during the seasons of 1880–1–2–4–5, and by two students in 1886. As the director was, in 1883, a member of the Maryland Oyster Commission, the outfit of the laboratory was that year moved from Beaufort into the Chesapeake Bay, and we occupied a building which we rented from the Normal School at Hampton, Va. As Hampton proved to be a very unfavorable place for our work we returned to Beaufort the next year, and we have accordingly spent five seasons at Beaufort.

During the season of 1886 the zoological students of the University were stationed at three widely separated points of the seacoast. A party of seven under my direction visited the Bahama Islands, two were at Beaufort, and one occupied the University table at the station of the U. S. Fish Commission at Woods Hole.

The party which visited the Bahamas consisted of seven persons, and our expedition occupied two months, about half of this being consumed by the journey.

The season which is most suitable for our work ends in July, and we had hoped to reach the Islands in time for ten or twelve weeks of work there, but the difficulty which I experienced in my attempts to obtain a proper vessel delayed us in Baltimore, and as we met with many delays after we started, we were nearly three weeks in reaching our destination.

We stopped at Beaufort to ship our laboratory outfit and furniture, but the vessel, a schooner of 49 tons, was so small that all the available space was needed for our accommodation, and we were forced to leave part of our outfit behind at Beaufort.

We reached our destination, Green Turtle Key, on June 2d, and remained there until July 1st. The fauna proved to be so rich and varied and so easily accessible that we were able to do good work, notwithstanding the shortness of our stay and the very primitive character of our laboratory. This was a small dwelling house which we rented. It was not very well adapted for our purposes, and we occupied as lodgings the rooms which we used as work rooms.

RECORD OF THE VARIOUS SESSIONS.

For the following brief records of the various sessions of the Chesapeake Zoological Laboratory I am indebted in large part to Prof. E. A. Andrews:

1878: 8 weeks, Ft. Wool, Virginia; 7 members. Brooks studied embryology of Lingula.

1879: June 25—August 8, Crisfield, Maryland; 11 members. Brooks studied the oyster. Three barges served as laboratory and quarters. Swarms of mosquitos led to the abandonment of this locality early in August, and the removal of the laboratory to Ft. Wool, until September 15.

1880: April 23—September 30, Beaufort, North Carolina; 6 members. Laboratory and quarters were in the Gibbs house. A steam launch was bought and the laboratory equipped by means of an appropriation from the University.

1881: May 2—end of August, Beaufort, North Carolina; 12 members. An "Elementary Seaside School" had been announced, with lectures by Brooks and S. F. Clarke; fee for the course, $25.

1882: May 1—end of September, Beaufort, North Carolina; 8 members.

1883: May 1—October 1, Hampton, Virginia. As a member of the Maryland Oyster Commission Brooks was obliged to spend this summer on the Chesapeake. The new machine shop of the Hampton Institute was rented as a laboratory, and a fast sloop was added to the equipment. Wm. Bateson there joined the party to study the development of Balanoglossus.

1884: June 1—September 19, Beaufort, North Carolina; 10 members. The illness of Brooks obliged him to return after a month, leaving the laboratory in charge of H. W. Conn. Bateson, who was again with the party, was also seriously ill.

1885: May 23—September 15, Beaufort, North Carolina; 11 members. Brooks became a licensed pilot to take the steam launch in and out of Beaufort Inlet.

1886: June 2—July 1, Green Turtle Key, Abaco, Bahamas; 7 members. The party left Baltimore, May 1, in a small Bay schooner, chartered by the day, with Brooks as pilot. With head winds, mishaps and a stop at Beaufort to take on laboratory furniture they did not reach their destination until June 2.

1887: March 1—July 1, Nassau, Bahamas; 12 members.

After this session, owing to financial losses on the part of the University, the Chesapeake Zoological Laboratory was temporarily suspended and its outfit dispersed.

1888 and 1889: Brooks, with some of his students, was at Woods Hole, Massachusetts, as naturalist in charge of the U. S. Fish Commission Station.

1891: May 26—September 1, Kingston, Jamaica; 15 members. The Chesapeake Zoological Laboratory was established at Port Henderson, on the harbor opposite Kingston.

1892: A party of three, in charge of Professor Andrews, was located at Alice Town, North Bimini, Bahamas. Brooks did not go.

1893: April 20—July 23, Port Henderson, Jamaica; 7 members. Brooks did not go and Dr. R. P. Bigelow was acting director.

1894: April 7—July 7, Beaufort, North Carolina; 9 members. Brooks was present.

1895: June 6—August 13, Beaufort, North Carolina; 4 members. Doctor Siegerfoos was acting director; Brooks was not present.

1896: April 29—July 30, Port Henderson, Jamaica; 4 members. Dr. F. S. Conant was acting director; Brooks was there for a while.

1897: June–September, Port Antonio, Jamaica; 12 members. Prof. James Ellis Humphrey was acting director. Humphrey died there of yellow fever, August 12; Dr. Franklin Story Conant contracted the fever there, and died on his return to Boston in September.

1898: Beaufort, North Carolina; 6 members. Prof. H. V. Wilson was director. In this and all subsequent years students went, with little or no aid from the University, to the U. S. Fish Commission Station at Beaufort.

1901–1906: Brooks was again at Beaufort in 1901 and 1903, and at the Marine Laboratory of the Carnegie Institution at Dry Tortugas, Florida, in 1905 and 1906.

In twenty years the Chesapeake Zoological Laboratory provided facilities for more than 160 workers, and approximately 200 papers were published as a result of these sessions. In reviewing this enterprise one cannot fail to be impressed with the great results accomplished with small financial outlay. For the purposes which Brooks had in mind the advantages of a laboratory whose equipment could be moved from place to place are most evident, and the need of such laboratories is not yet past. May the Chesapeake Zoological Laboratory, or some other worthy successor, continue this work, so well begun by Brooks!

On these various expeditions Doctor Brooks was interested not merely in zoology, but also in botany and geology, and in the customs, characters, and histories of the people among whom he was living. He took keen interest while in the Bahamas in following the route of Columbus from island to island. He advocated the establishment of a Columbus Biological Station in memory of the great discoverer. He was particularly interested in the Indians found by Columbus on these islands, and he wrote a very interesting popular account of them, and prepared a monograph on their physical anthropology based on a study of a collection of their skulls. His love of the artistic was shown in his vivid pen picture of "Life on a Coral Island" and "Aspects of Nature in the West Indies." The following letter, written to his brother while on his last scientific expedition, describes in his vivid manner a trip which he made into the Everglades:

THE JEFFERSON,
KEY WEST, FLORIDA, March 21, 1906.

DEAR CHARLES: I am in the "hottest place in the U. S." in an overcoat and my thickest underclothing. I am to get off to the Dry Tortugas tomorrow, on an excursion of army officers, after having been ten days on the journey. It has been a pleasant and profitable journey on the whole, but the delays have been very tiresome.

Among other side excursions I have been where very few white men have been—into the Everglades—which I found most interesting and very different from what our geographies lead us to expect. The whole interior of southern Florida is a great lake of pure spring water, covered with wild rice and reeds, and with a hard bottom, with no mud. It is surrounded by a rim of limestone about 30 feet above the level of the lower land, and it overflows in rivers wherever the rim is low. We went up a river, very deep and rapid, for about twenty miles, to the rapids, and we got up the rapids by towing on the overhanging branches to the top, where the big river at once became lost in the great shallow lake. We picked out a tree on a little island about five miles away, and pushed through the tall reeds until we reached it. We climbed the tree, and as far as we could see there was nothing but reeds in all directions. After eating our lunch we pushed back through the reeds and struck our river again; but I could not help wondering what would happen to us if we missed the river. The trip down the rapids, about half a mile, was most exciting, and I was nearly torn out of the canoe by some low branches.

On our way back we visited an alligator farm, where they hatch, from stolen eggs, the little alligators that are sold in our northern cities. They also deal in rattlesnakes and owls and hawks. In one pond they had the biggest American crocodile known. He is 19 feet long, big enough to drown a horse, and he is fed on live hogs. It must be very exciting to rob the nests of alligators and crocodiles. If you ever have the opportunity to visit southern Florida you should do so.

Miami is the prettiest tropical town I have ever seen and well worth a visit.

Yours affectionately, W. K. Brooks.

PRINCIPAL PUBLICATIONS.

As a scientific investigator Brooks showed sound judgment, philosophic insight, and breadth of view. His method of work, like his manner of life, was calm and slow. He was not a prolific writer, and of the one hundred and fifty titles, more or less, which appear in his bibliography, not less than thirty are preliminary notes or republications of other papers. Many of these papers are brief notes or abstracts, so that his total number of important contributions does not exceed one hundred. These were distributed over thirty-five years of his active life, so that he did not average more than three such papers a year. He did practically no research work on vertebrates, and his work on invertebrates was confined almost exclusively to five groups, viz.: pelagic tunicates, mollusks, Molluscoida, higher

Crustacea, and Hydromedusæ. Altogether he published seventeen papers on tunicates, twenty-six on mollusks (fourteen of these on the oyster), three on Molluscoida, fifteen on decapod Crustacea, and sixteen on Hydromedusæ. In addition to these he published five or six general works and about sixty theoretical and popular articles, reviews, etc.

All of his papers, even those which deal with the most detailed and technical subjects, are generally understandable and as little technical as possible. As in his lectures, he took little for granted, began at the beginning, and kept his main topics prominent; moreover, he wrote in an entertaining manner, and his articles contain a certain popular quality while not lacking in scientific accuracy.

His first important paper was on the "Embryology of Salpa," and many of his later works, some of them monumental monographs, were devoted to the anatomy, embryology, and classification of this group of pelagic tunicates. Among these papers the most important are the following: "The development of Salpa," "Origin of the eggs of Salpa," "The anatomy and development of the salpa chain," "Monograph of the genus Salpa," and the "Pelagic Tunicata of the Gulf Stream." His latest work, left unfinished, and for which he had prepared hundreds of beautiful drawings, was a continuation of his great monograph on the genus Salpa. These works on the tunicates are too extensive and complicated to be summarized briefly, but some of his more important conclusions are the following:

1. In his earlier papers Brooks maintained that there is not a regular alternation of generations in the life cycle of salpa, between the solitary individuals and those united into chains, as had been generally held since Chamisso's work on salpa, but that the solitary salpæ are females, and that they produce by budding the chain individuals, which are males. Into each of the chain salpæ, before it is set free, an egg is placed, which comes to maturity in the chain form, and ultimately develops into another solitary individual, thus completing the life cycle. In his later works, as Professor Metcalf has pointed out in a letter to the writer, Doctor Brooks departed in several respects from this early conception. He showed very clearly that the solitary salpa is an immature sexual form, which passes its

germinal cells into the chain individuals, where they reach maturity. Since these germinal cells give rise to both ova and spermatozoa, both solitary and chain forms may be considered potentially bisexual, though the solitary forms never contain mature germ cells.

2. In the formation of the salpa chain a stolon, or stalk, which grows out from the solitary salpa is constricted at intervals, thus giving rise to the members of the chain. The stolon is bilaterally symmetrical, its planes of symmetry coinciding with those of the solitary salpa which bears it, and, at first, the planes of symmetry of every member of the chain coincide with those of the stolon and of the solitary salpa. Very soon, however, a twisting of the chain occurs which leads to the formation of a double row of salpæ, each row with the dorsal surfaces of its members turned outwards, while the ventral surfaces of the two rows are turned toward one another, and the right sides of one row and the left sides of the other are turned toward the base of the stolon.

3. The salpa embryo, which develops from the fertilized egg into the solitary salpa, "is blocked out in follicle cells which form an outline or model of the general features of the embryo. While this process is going on the development of the blastomeres is retarded, so that they are carried into their final positions in the embryo while still in a very rudimentary condition. Finally, when they have reached the places which they are to occupy, they undergo rapid multiplication and growth and build up the tissues of the body directly, while the scaffolding of follicle cells is torn down and used up as food for the true embryonic cells."

4. The salpa embryo is connected by a placenta with one of the members of the chain, and is nourished by placenta cells which migrate from the placenta into the embryo. The placenta is thus an organ which nourishes the embryo, not by the transfusion of blood, but by means of giant cells which in the placenta receive nourishment from the blood of the parent, and then migrate into the embryo, there to break down and supply food to the embryo.

But Brooks' work on salpa is not merely a description of the anatomy, embryology, and classification of these interesting tunicates, for it deals in original and philosophical manner with such problems as the origin of chordates, the origin of pelagic animals, the discovery of the ocean bottom, and the effects of this upon the evolution of life.

Another major line of his work was on the anatomy and embryology of the Mollusca. One of his first papers was on "An organ of special sense in the lamellibranchiate genus Yoldia," this sense organ being a long retractile tentacle, half way between the siphon and the lower edge of the mantle on the right side. This paper was soon followed by one on "The embryology of the fresh-water mussels," in which the entire development of *Anodonta implicata* is described in brief outlines, and the conclusion is reached that the larva, or glochidium, is a specially modified stage, adapted to a special purpose, and having no bearing on the question of the origin of the group. Both of these papers are brief abstracts of three pages each, and they were read at the meetings of the American Association for the Advancement of Science in 1874 and 1875. In a paper "On the affinities of the Mollusca and Molluscoida" (1876) he concluded that Brachiopoda have been derived from Vermes, Polyzoa from Brachiopoda, and the Molluscan Veliger (the prototype of the Mollusca) from Polyzoa. The Lamellibranchiata he held to be a side branch, and not ancestral to the group of mollusks as a whole. Later (1879), in his paper on "The development of Lingula and the systematic position of the Brachiopoda," he held that the Rotifera, Polyzoa, and Veliger were three branches which early diverged from the vermian stem. The Brachiopoda he held to be the most highly specialized members of the polyzoan branch, the Mollusca the most highly specialized of the Veliger branch. For these three branches he proposed the name Trochifera.

In his "Observations upon the early stages in the development of the fresh-water pulmonates" (1879) he observed the rhythmical nature of the process of cleavage, the formation of the ectoderm from the clear cells at the animal pole of the egg, the formation of the endoderm from the macromeres at the vegetative pole, and the lack of a continuous mesodermal layer in the embryo. He devoted particular attention to the fate of the blastopore and the origin of the digestive tract; but since his observations were made exclusively on living material, he fell into several errors, mistaking the shell gland for the mouth, which he maintained appeared opposite the original position of the blastopore, and concluding that the macromeres fuse together, and afterwards bud out cells which form the alimentary canal. In the main the same remarks apply to his "Preliminary observations on the development of the prosobranchiate gasteropods," which appeared in the same year (1879). In this paper, and in a subsequent one on the "Acquisition and loss of a food yolk in molluscan eggs," he devoted much attention to what is now known as the yolk lobe, or polar lobe, which he regarded as a "food yolk." This he believed to be in process of being lost in some cases, as, *e. g.*, the oyster, while it was being acquired in others. It is needless to say that this explanation of this problematical yolk lobe is no longer found to be satisfactory. In a brief paper on the "Development of the digestive tract in molluscs" (1879) he reiterates his mistaken view that in gasteropods and lamellibranchs the blastopore is converted into the shell gland, and that the mouth forms at the opposite side of the embryo. With the exception of a single paper, published in collaboration with one of his students in the last year of his life, this list comprises all of his publications on the gasteropods. The paper just mentioned is entitled "The origin of the lung in Ampullaria" (1908), and is based upon the study of material which he obtained on his trip into the Everglades in 1906 (see p. 53). In brief, the conclusion of this paper is that the lung of this prosobranch has no ancestral connection with the lungs of pulmonates. "The gills, the lung, and the osphradium of Ampullaria arise simultaneously, or nearly so, and they must be regarded as a series of homologous organs specialized among themselves in different directions."

During the second session of the Chesapeake Zoological Laboratory material was collected for a study of the later stages in the development of the squid, *Loligo pealii,* which resulted in the publication of two papers, one "The development of the squid," the other "The homology of the cephalopod siphon and arms." The most important conclusions of these papers are: (1) That the embryonic record of the Cephalopoda "has been simplified to a degree which is without parallel in the animal kingdom, and it is hardly too much to say that the ontogenetic process furnishes us with no knowledge whatever of the phylogeny of the group;" (2) that the yolk sac of the cephalopod embryo is the homologue of the gasteropod foot; (3) "that if the epipodal folds of the gasteropod are regarded as homologous with the cephalopod siphon, the arms of the cephalopod must be regarded as independently acquired structures; whereas if we regard the arms as modifications of the epipodal folds, we must consider the four siphon folds as independently acquired structures;" and (4) "the common ancestor of the gasteropods and cephalopods must have been an unspecialized form, and we cannot expect any valuable results to follow from the attempt to compare any part of the body of a cephalopod with structures which, like the epipodal folds, are not common to the Gasteropoda, but somewhat exceptional."

All his other publications on the Mollusca, fourteen in number, deal with the development and propagation of the oyster. In 1878, during the first session of the Chesapeake Zoological Laboratory, he attempted to find young oysters in the gills of the female, as had been described in the case of the European oyster, but without success. In May, 1879, he went to Crisfield, Maryland, the center of the oyster industry on the Chesapeake, and settled down to study the problem of the development of the oyster. "On Monday, the 21st," he says, "I opened a dozen fresh oysters, and found three females, with their ovaries filled with ripe ova, and one male, with ripe spermatozoa. I mixed the contents of the reproductive organs of these four oysters, and within two hours after the commencement of my first experiment I learned by the microscope that the attempt at artificial fertilization was successful, and that nearly all of my eggs had started on their long path toward the adult form. . . . I have accumulated enough evidence to show, beyond the possibility of doubt, that so far as the oysters of the Chesapeake Bay, during the summer of 1879, are concerned, the eggs are fertilized outside the body of the parent, and that during the period which the European oyster passes inside the mantle cavity of its parent, the young of our oyster swim at large in the open ocean."

This was the beginning of his many publications and his years of labor on the development and propagation of the oyster. His first paper on "The development of the American oyster" was very favorably received, and was republished in whole or in part in many American and foreign journals. In recognition of the importance of this work, he was awarded a medal by the Sociètè d'Acclimatation of Paris. In 1882 the General Assembly of Maryland established a commission to consider ways and means to "Perpetuate the oyster beds of the Chesapeake," and Doctor Brooks was appointed chairman of this commission by the governor. The university released him from active duties, in order that he might devote his entire time for eighteen months to the study of the economic aspects of the oyster problem. A laboratory was established at Hampton, Virginia, where experiments were carried out on the propagation of oysters, and extensive surveys of oyster beds were made. The report of this work was published in 1884, in a quarto of 183 pages, 7 maps, and 13 plates. The legislature paid little attention to the recommendations of this report, and Doctor Brooks undertook by public lectures and newspaper articles to arouse public interest in the subject. To this end he published in 1891 a popular work on this subject, entitled "The Oyster," which was republished in a second edition in 1905. His absorption in this work was so complete that he talked oysters in season and out of season. The story is current that at a university reception a society woman attempted to engage him in small talk; he listened mutely for a while, and then was heard to say suddenly, and with animation, "Madam, the Maryland oyster is being exterminated."

Finally, in 1906, the legislature of Maryland passed a law for the protection and propagation of oysters along substantially the lines advocated by Doctor Brooks, and the satisfaction which he felt in this happy culmination of his long campaign was very great.

A third line of work to which he devoted much attention was the embryology and larval history of the higher Crustacea,* and altogether about fifteen papers dealing with these subjects were published during a period of fifteen years, from 1879 to 1892, his first contribution on the larval stages of *Squilla empusa* representing some of the "Scientific Results of the Chesapeake Zoological Laboratory" for 1878. At Beaufort, in 1880, his interest in this subject deepened, for he saw in the structure and metamorphosis of these animals a means of attacking several larger problems, such as the laws of larval development, the analysis of secondary adaptations, and the meaning of metamerism in both lower and higher animals.

The works by which Professor Brooks will be best known to all future students of crustacean zoology are undoubtedly his large monograph on "Lucifer: a study in morphology," published in the Philosophical Transactions of the Royal Society of London for 1882, and his "Report on the Stomatopoda," which appeared as part of the sixteenth volume of the Scientific Results of the Challenger Expedition in 1886. Not only did he discover that the shrimp, Lucifer, emerged from the egg as a true Nauplius, but, what was even more novel, that the egg itself underwent a total and regular segmentation, and gave rise to a gastrula of the invaginate type. After tracing the metamorphosis through nine distinct stages, and making exhaustive comparisons, he concludes that the highly peculiar segmentation and gastrulation are secondary, but that the three-jointed Nauplius represents a true ancestral form, "and nothing but the supposed necessity of believing that the primitive Crustacea had a large number of somites and appendages opposes this view." He shows that the serial and bilateral homology, so evident in the Crustacea, cannot be explained by supposing that the ancestors of the Crustacea represented a community of independent parts. In his Report on the Stomatopoda he considers this subject again, and concludes that serial homology may be due "to heredity from the same part of the developing egg, rather than from a remote ancestor." The report on the Stomatopoda is distinguished by the great ingenuity and mastery shown in classifying all of the known larvæ of this sub-order and in tracing them to their proper genera, for he had no living material to work with, excepting the two species—*Squilla empusa* and *Lysiosquilla excavatrix*—which he had studied from the southern coast of the United States.

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*For assistance in preparing this abstract of Brooks' work on the Crustacea, the writer is indebted to Prof. F. H. Herrick.

During the period from 1880 to 1883, Professor Brooks undoubtedly contemplated the preparation of a work on the higher Crustacea, of greater scope than anything which he later produced, and this was only partially fulfilled in the publication, in collaboration with F. H. Herrick, of "The embryology and metamorphosis of the Macrura," in the Memoirs of the National Academy of Sciences for 1892. Moreover, it should not be overlooked that one of his most notable papers, in which he described how a Stomatopod—*Gonodactylus chiragra*—was reared, for the first time, from the egg, and in which he traced all its successive stages in the living state, appeared as Chapter III of the latter work.

Another group of animals to which Professor Brooks devoted a large amount of attention is that of the Hydromedusæ. In the study and drawing of these beautiful and delicate forms he combined the enthusiasm of the naturalist and that of the artist. From 1880 to 1886 he published seven papers on the Medusæ, chiefly of the Beaufort region, culminating in his monograph on "The life-history of the Hydro-medusæ: A discussion of the origin of the Medusæ and of the significance of metagenesis" (Memoirs Boston Society Nat. Hist., Vol. 3, 67 pp., 8 plates). This work contains an account of his observations on the life-history of a Narcomedusa, a Trachomedusa, an Anthomedusa, and a Leptomedusa, the four species selected for study being "among the most abundant and characteristic of our Southern coast, yet none of them have been well studied." This is one of the most beautiful, complete, and satisfactory papers which Doctor Brooks wrote; the observations are beautifully recorded, the evidences from his own work and that of others are completely marshalled, and his conclusions give the satisfaction which comes from a broad outlook, an intimate knowledge and a logical presentation of a great subject. In brief, his conclusion as to the origin of the Medusæ and the significance of metagenesis are these: (1) The remote ancestor of the Hydromedusæ was a solitary swimming hydra, or actinula, with no medusa stage, but probably with power to multiply by budding; (2) this became more highly organized, better fitted for swimming life, until it was converted into a medusa, with swimming bell and sense organs, developing directly from the egg, but exhibiting during growth the stages through which the race had passed; (3) after this the larva derived some advantage in becoming attached, either as a parasite or semiparasite, and in this condition it budded off other larvæ, all of which became medusæ; (4) the sessile life of the larva was so advantageous that it was perpetuated by natural selection and the primary larva lost its tendency to become a medusa, and remained a sessile hydra, budding off larvæ which became medusæ; (5) the primary larva acquired power to produce other larvæ, which remained permanently in the hydra state; and (6) finally, the communities thus formed became polymorphic by division of labor, and the sessile habit became so advantageous that the free medusæ became degraded into medusa buds on the bodies of the sessile hydras, or on the blastostyles. Following this monograph, he published six shorter papers on Hydromedusæ, the last appearing only one year before his death. A monograph on American jelly fishes, which he had worked upon for many years, was never completed, though many of the drawings and descriptions were used in some of the other papers named.

He wrote but one text-book, his "Handbook of Invertebrate Zoology," 1882, but this was so excellent that it has been a model for many subsequent books on that subject, and it is probable that if it had been handled by a larger publishing house its success would have been much greater. He was also the author of many scientific articles of a popular sort, in which kind of writing he showed unusual ability. He was inclined to look upon various human problems, such as the education and political position of woman, from the standpoint of zoology, and his popular discussions of the possible improvement of the human race, of instinct and intelligence, of heredity and variation, etc., were both novel and suggestive.

His chief interest was always on the philosophical side of biology, and into this he put a large part of his life work.

Even the special researches, some of which have been named above, were permeated by philosophical inquiry, and most of his books and later contributions were devoted to the deeper philosophical meanings of vital phenomena.

As a boy he had read the works of Darwin, and had been immensely impressed by them, and to the last he yielded to no one in his admiration and reverence for that great master. Probably no other disciple of Darwin was more thoroughly acquainted with his works, and very frequently when criticisms of Darwinism appeared he would point out the fact that the critic did not understand what Darwinism is, or that Darwin had already met and answered the objection raised.

One of his earliest papers, entitled "A provisional hypothesis of pangenesis," which he read before the American Association for the Advancement of Science in 1876, contained the germ of many of his later theories and speculations. This germ is the hypothesis that, whereas fully established peculiarities are transmitted by asexual reproduction as well as by the ovum, new characteristics are transmitted only through gemmules, which are stored in the reproductive glands of the male, and are transmitted to the egg in fertilization. Gemmules from the body of the female may pass into the ova, but there is here no organ for the aggregation and transmission of them. "The male element is thus the originating, the female the perpetuating factor in the reproductive process. The female is conservative, the male progressive."

This speculation, which he sought to support by many observations, became the basis of a volume of 336 pages, entitled "The law of heredity," which he published in 1883. This volume, however, contained much of value besides the speculation named. In some respects it anticipated the Germ-plasm theory of Weismann and the Mutation theory of De Vries, and it won the highest commendation from Huxley and other leaders in biology. Like many other profound thinkers on the subject of heredity, he recognized that no hypothesis of epigenesis offers a satisfactory explanation of heredity, and that there is no escape from some form of the evolution hypothesis. The form which he adopts is Darwin's hypothesis of pangenesis, with the modification suggested above. He points out that it is not necessary to assume that the germ is as complicated as the adult, since under certain conditions the descendants of a single cell may become modified in several divergent directions. He maintains that Darwin's hypothesis may be so simplified that the gemmules may be few in number, simple in their properties, and not infinitely small. Nevertheless, this theory requires us to believe that the egg of one of the higher animals is complex beyond our powers of conception. It is interesting to note that he discusses (p. 131) those cases in which a hybrid resembles one parent or the other, but not both (what we now know as Mendelian inheritance), and he suggests a possible explanation by means of his hypothesis of pangenesis. In similar manner he discusses saltatory evolution (pp. 157, 296), and agrees with Huxley, Galton, and Mivart that nature does make considerable jumps (mutations), especially in the case of domesticated animals and cultivated plants. As instances of this kind he cites the sudden appearance of spike-horned bucks in the species *Cervus virginianus,* the ancon ram, the japanned peacock, and several similar cases among plants, and he "points out that our view of the cause of variation implies that any particular change should in itself be a fruitful source of still greater modifications, so that as soon as a tendency to vary becomes established it will continue to increase until an equilibrium is again established by the natural selection of those modifications which are adapted to the environment."

With regard to the determination of sex, he concludes that "sex is not determined by any constant law; that in certain animals and plants the sex is determined by certain conditions, while in other groups it is determined by quite different conditions" (p. 317). These are only a few of the subjects of present-day interest which are discussed in this book, and which he attempts to explain by his modified hypothesis of pangenesis, and although this hypothesis has no defenders at present, the book is still stimulating and suggestive.

It is interesting, and to many of his followers saddening, to see how far Brooks wandered in later life from the study of the physical phenomena of heredity and variation into metaphysical speculation. In two papers written in the last years of his life, one of them entitled "Heredity and variation, logical and biological" (1906) and the other his address before the Seventh International Zoological Congress in 1907, entitled "Are heredity and variation facts?" he concludes that these terms "represent only imperfect mental concepts, and not facts, and that neither heredity, nor variation nor species can reside in germ cells, nor in chromatin, nor in gemmules. The gradual disappearance of attempts to invent evolutionary hypotheses to account for individual development or ontogeny, and the return to a more epigenetic standpoint . . . seems to me a notable reformation. Ancestral development is as epigenetic as individual development. The being of an individual is not in itself, but in reciprocal interrelations between it and its environment. If these things are true, is it not time to have done once for all with the pre-Darwinian metaphysical notion of species as something which resides in germ cells and is handed down by a substance of heredity?"

This brings us to a consideration of his philosophical and metaphysical writings to which the last ten years of his life were devoted almost exclusively. The publications of this period include some eighteen or twenty papers on philosophical subjects, culminating in the book into which he put the best efforts of his life, and by which he hoped to be longest remembered, viz.: "The foundations of zoology" (1899). This book consists of a series of lectures which were originally delivered at Columbia University, and were published in the Biological Series of that institution. It deals with many subjects fundamental not only to zoology, but to science and philosophy in general. The keynote of this book is found in the following extracts from the introductory lecture: "I shall try to show that life is response to the order of nature—in fact, this thesis is the text of most of the lectures; but if it be admitted, it follows that biology is the study of response, and the study of that order of nature to which response is made is as well within its province as the study of the living organism which responds." Among such responses to the order of nature are various forms of adaptation, correlation, instinct, intelligence, volition, and responsibility, and the question arises as to whether such responses are mechanical. "I am myself unable to discover, in the present status of biology, any demonstration of error in the assertion that life is different from matter and motion," but "I cannot find any contradiction between anything we find in our nature and the ultimate reduction of all nature, including all the phenomena of life and of mind, to mechanical principles; for most students of the principles of science agree that natural knowledge is no more than the discovery of the order of nature. . . . Order is no explanation, but a thing to be explained." "It is a hard thing," says Berkeley, "to suppose that right deductions from true principles should ever end in consequences which cannot be maintained." To which Brooks responds: "In my opinion there is nothing in the prevalence of mechanical conceptions of life and mind, or in the unlimited extension of these conceptions, to show that this hard thing to suppose is true."

It is as impossible to summarize this book as it would be to summarize the Book of Proverbs, or the Meditations of Marcus Aurelius. It is, indeed, a compilation of many meditations which appear to have been written down at many different times, and afterwards joined together with more or less care. The result is a book which contains more pithy, quotable sentences than can be found in any other book dealing with biology with which I am acquainted, but at the same time it is a book which is difficult to analyze, and in places difficult to understand. The titles of the chapters will, in a general way, give the trend of the book; these are: "Huxley and the problem of the naturalist," "Nature and nurture," "Lamarck," "Migration in its bearing on Lamarckism," "Zoology and the philosophy of evolution," "A note on the views of Galton and Weismann on inheritance," "Galton and the statistical study of inheritance," "Darwin and the Origin of Species," "Natural selection and the antiquity of life," "Natural selection and natural theology," "Paley and the argument from contrivance," "The mechanism of nature," "Louis Agassiz and George Berkeley." In the course of these lectures very many important facts and observations on the topics suggested are introduced, and the book is of value from this more usual standpoint of science, but attention is chiefly directed to the underlying philosophical significance of these phenomena. On the whole his chief points of view may be summarized in his oft-quoted remark of Aristotle, that the "essence of a living thing is not what it is made of nor what it does, but why it does it," or, as he expresses it elsewhere, "the essence of a living thing is not protoplasm, but purpose;" and in the further statements which he draws from Berkeley, that "nature is a language," that "phenomena are appearances," and that "natural laws are not arbitrary nor necessary, but natural, *i. e.,* neither less nor more than one who has the data has every reason to expect." His system of philosophy was profoundly influenced by the writings of George Berkeley; his language resembles in its force and beauty the essays of Huxley, but his application of these to the foundations of science is his own.

On his fiftieth birthday, March 25, 1898, his former students united in presenting to him an oil portrait of himself (see page 71), together with a congratulatory address, and at the end of his book on the "Foundations of Zoology" he added on this date the following note:

> For you who have, at this time, for my encouragement, called yourselves my students, I have written this book which has been my own so long that I should part with it with regret, did I not hope that, as you study the great works to which I have directed you, you may still call me teacher. If you are indeed my students, you are not afraid of hard work, so in this day of light literature, when even learning must be made easy, you must be my readers, and you must do double duty; for I take the liberty of a teacher with his pupils, and ask that, after you have read the book, you will some day read it again; since I hope that what may seem obscure, may, on review, be found consistent and intelligible.

Much that he has written still seems to me obscure, although I have read it more than once, but I bear in mind his parting request, and in the meantime profit by that which I do understand, and am charmed by the classical and almost poetical diction in which it is written. Whatever one may be inclined to say of his conclusions and theories, it cannot be denied that in an age when biological investigators have been content with discovering phenomena, he attempted to go back of phenomena to their real meaning and significance and to point out the relationship of these newly-discovered phenomena to the great current of philosophy which has flowed down to us from the remote past.

In his review of this book, under the caption "A sage in science," David Starr Jordan said:

> Brooks' lectures on the Foundations of Biology constitute a book that will live as a permanent addition to the common sense of science. It belongs to literature as well as to science. It belongs to philosophy as much as to either, for it is full of that fundamental wisdom about realities which alone is worthy of the name of philosophy. Writers of literature have been divided into those with quotable sentences, such as Emerson and Thoreau, and those whose style runs along without break in the elucidation of matter in hand, as Hawthorne and Irving. To the former class Brooks certainly belongs. His lectures are full of nuggets of wisdom, products of deep thought as well as of careful observation. There is not an idea fundamental to biology that is not touched and made luminous by some of these sagacious paragraphs. Whether it be to show the significance of some unappreciated fact, or to illustrate the true meaning of some complex argument, or to brush away the finespun rubbish of theory, the hand of the master is seen in every line. . . . The stones which Doctor Brooks has chosen as "Foundations of Zoology" will remain for centuries, most of them as long as human wisdom shall endure. The volume is a permanent contribution to human knowledge, the worthy crown of a life of wise thought as well as of hard work and patient investigation. The biologists of America have long since recognized Doctor Brooks as a master, and this volume, the modern and scientific sequel to Agassiz's "Essay on Classification," places him in the line of succession from the great interpreter of nature, whose pupil and friend he was.

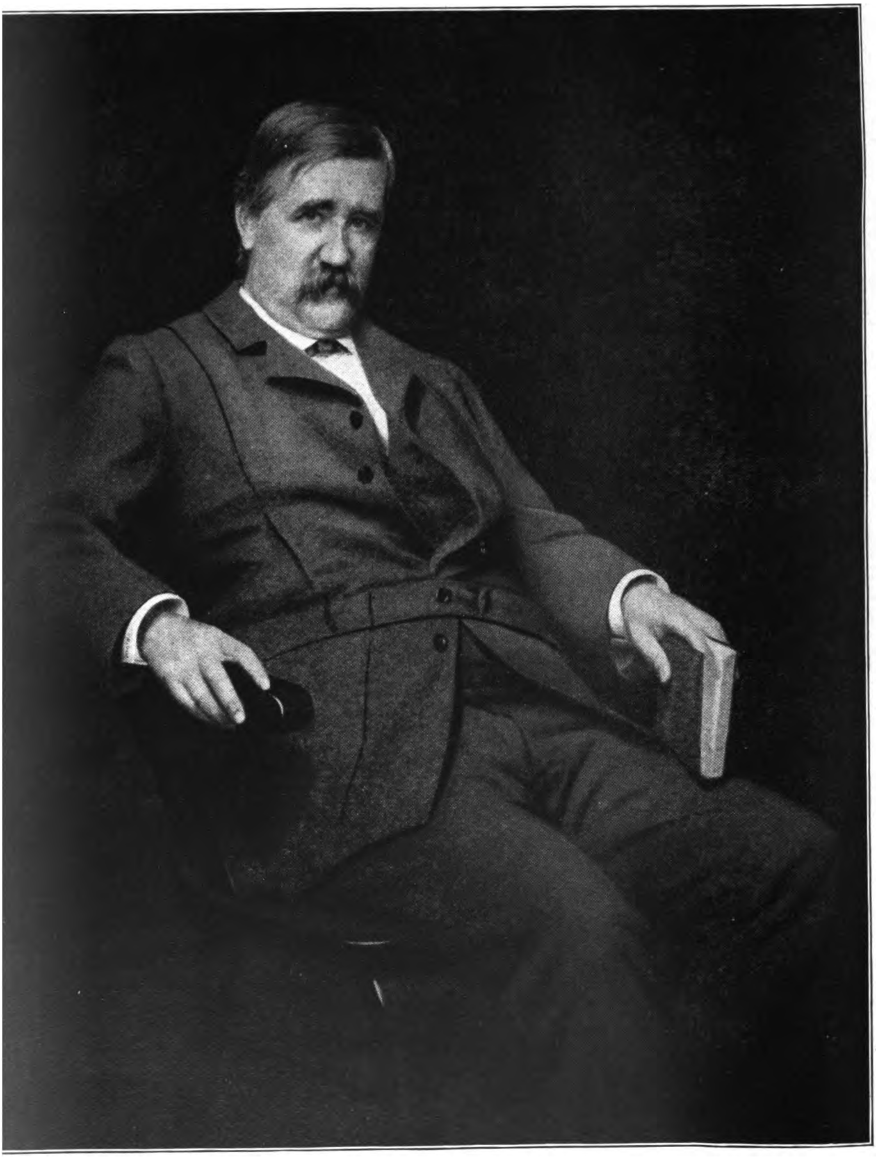
HONORS, DEGREES, OFFICIAL POSITIONS.

His abilities received early and generous recognition. Apart from his university advancement he received many honors. The honorary degree of LL. D. was conferred upon him by Williams College in 1893, by Hobart College in 1899, and by the University of Pennsylvania at the Franklin Bicentenary in 1906. In 1884, at the age of thirty-six, he was made a member of the National Academy of Sciences. He was chosen a member of the American Philosophical Society in 1886, and a Councillor of the Society in 1906; an Associate Fellow of the American Academy of Arts and Sciences in 1892; resident member of the Boston Society of Natural History in 1875, and corresponding member in 1877; corresponding member of the Academy of Natural Sciences of Philadelphia in 1887; honorary member of the New York Academy of Sciences in 1898. He was also a member of the American Society of Zoologists, the New York Geographical Society, the Society of American Wars. He was a fellow of the American Association for the Advancement of Science, and of the Royal Microscopical Society.

As a result of his investigations on the development of the oyster, he was appointed by the governor of Maryland to be chairman of the Oyster Commission of that State; and he was also made Member Protector, Classe Peche et Pissiculture d'Exposition universelle d'Anvers; he also received the medal of the Société d'Acclimatation of Paris for his oyster work. A Challenger medal was given him for his work on the Challenger Reports; and he received a medal at the St. Louis Exposition of 1904, where he gave one of the principal addresses. He was Lowell Lecturer in Boston in 1901; one of the speakers at the American Museum of Natural History on the occasion of the unveiling of busts of American men of science during Convocation Week, 1906; and he gave one of the principal addresses at the Seventh International Zoological Congress in Boston, in 1907.

For nearly twenty years he was a trustee of the Marine Biological Laboratory at Woods Hole, Massachusetts; and in 1888 he was Scientific Director of the U. S. Fish Commission Station at Woods Hole. He was editor of the Results of the Chesapeake Zoological Laboratory; co-editor, with Professor Martin, of the Studies from the Biological Laboratory of the Johns Hopkins University; editor of the Memoirs from the Biological Laboratory, and a member of the board of editors of the Journal of Experimental Zoology.

All of these honors he prized highly, though modestly, and he rarely mentioned them except in facetious vein. It was characteristic of him, however, that he not infrequently mentioned with pride the fact that he held a U. S. Inspector's Certificate, licensing him as a pilot.



PERSONALITY.

Professor Brooks was a man of strongly marked individuality. In personal appearance he was short and stout, with straight dark brown hair and heavy dark brown moustache and eyebrows. While in Cambridge, and during the earlier years of his residence in Baltimore, he wore a full bushy beard. He sometimes allowed his hair to grow long, apparently because he disliked to take the time to have it cut. He used to say jocosely that he envied the man who did not need to have his hair cut, and who never wore a collar or necktie. He was generally careless, or rather thoughtless, of dress, and mere conventionalities counted for little with him. His best known portrait is the one painted by Thomas C. Corner, and presented to him by some fifty of his former pupils on his fiftieth birthday, March 25, 1898, a photographic copy of which appears on the opposite page. This portrait was afterwards loaned to the Johns Hopkins University, and it now hangs among the portraits of other distinguished professors of the university in McCoy Hall. It represents him in characteristic attitude, sedentary, meditative, careless of dress, and with that peculiar uplift of the eyes which with him usually preceded speech.

He was slow and deliberate in his movements and speech, and undemonstrative in manner. In general he talked little, and in a low tone. When he had occasion to speak more loudly his voice assumed a rather high and piping quality. With him talking meant expressing ideas, not merely passing the time, and if he had no answer ready when a question was asked him he usually gave no answer until he was ready—it might be several days later—when he would answer as naturally as if the question had been asked only a moment before. These characteristics made him appear somewhat unique and picturesque, and gave rise to many charming anecdotes about him which his students and friends relate with merriment, but real affection.

In spite of his quiet reserve he was usually a very companionable man, and his company was sought and prized by his friends. On his part he was fond of his friends and neighbors, though he was often silent and absorbed in thought. At such times he would occasionally interrupt his quiet reflections by some thoughtful and unexpected remark, such as, "The term supernatural is due to a misconception of nature; nature is everything that is."

His humor was quiet but genuine; he enjoyed a good joke, and would sometimes relate humorous stories, but never any of questionable propriety. His laugh was never loud, and his amusement was shown by a quiet chuckle and twinkling eyes. In particular he enjoyed telling of odd and interesting persons whom he had known, and of the amusing behavior of animal pets. For a puppy that destroyed a copy of Shakespeare he professed a high regard, but one that chewed up cheap novels was a worthless rascal.

His love of animals was deep seated, and between him and his pets there was genuine companionship. In particular his great dog "Tige" was his constant companion for many years. This "noble dog," as Prof. William James has called him, was seven-eighths St. Bernard and one-eighth mastiff, and weighed nearly 100 pounds. He lived with his master during his life at Cambridge, and later accompanied him to Baltimore, and many who knew Doctor Brooks in those days remember how nearly inseparable he and his dog were. On one occasion, when Professor Brooks was living in the country near Baltimore, he took an early train to the city, and put "Tige" in the baggage car. Before the train started "Tige" jumped out, and then, missing his master, he raced after the train and kept within sight for two and one-half miles, when he was lost to view; but he appeared at the laboratory several hours later, and quietly laid down at his master's feet. The affection which Brooks had for this dog was very great, and after "Tige's" death he was often mentioned as if he had been a dear human companion.

For another favorite dog which had been lost in transit between Baltimore and North Carolina, Brooks employed a man to make careful search over the entire line of travel, not because the dog was of commercial value, but because of his affection for him. His attitude toward all animals and plants is beautifully expressed in his introductory lecture on the "Foundations of Zoology," p. 17: "As for myself, I try to treat all living things, plants as well as animals, as if they may have some small part of a sensitive life like my own, although I know nothing about the presence or absence of sense in most living things; and am no more prepared to make a negative than a positive statement."

Professor Brooks was interested in the welfare and practical needs of his fellow-men. In 1879 he gave part of an elementary course in biology for the teachers of the Baltimore schools. In 1882 he lectured before the employees of the Baltimore and Ohio Railroad on "Methods of locomotion in animals." He was also instrumental in establishing a public aquarium in Druid Hill Park. But his principal work of a practical character was on oyster and fish culture. By lectures, newspaper articles, and books he sought to arouse public interest in the great possibilities for public good which lay in these "harvests of the seas."

His sense of honor and justice was highly developed and his indignation was aroused when any case of injustice or abuse of power came to his notice. In particular he respected the rights of servants and the poorly educated, and he resented any infringement of these rights. While at Nassau, a merchant of the town tried to compel Doctor Brooks to pay him the wages of a negro servant of the laboratory. Doctor Brooks refused to do this unjust act, as he regarded it, and he resisted all pressure which was brought to bear to compel him to do this, even at the risk of being unable to sail on the steamer on which he had engaged passage. With a sense of obligation, unusual and perhaps exaggerated, he held that the university which employed him was entitled to all that he might earn by outside work; fortunately for him his university recognized no such obligation.

He was occasionally very happy in the use of scriptural language, illustrations, and quotations. He acquired his familiarity with the Bible in his grandfather's family, where it was read daily. His familiarity with the scriptures was often shown in his writings and conversation. On one occasion, in a discussion of Weismann's essay on "Life and Death," in which, as is well known, Weismann claims that death is not a necessary and primary characteristic of living things, but one which has been acquired, one of the students asked whether such a view was not contrary to religious teaching. Professor Brooks at once replied: "As I remember it, St. Paul teaches that death was not an original corollary of life, for he says 'by sin came death.'"

His nature and cast of mind was strongly reverential, and he could be said to be religious in the higher sense, although he long ago ceased to attend church or to take any interest in the doings or affairs of religious bodies. A few years before his death he talked with the writer upon the subject of immortality, and maintained that faith in immortality was in no sense unscientific. His attitude on these things may be inferred from the following extracts from the "Foundations of Zoology":

> If any believe they have evidence of a power outside nature to which both its origin and its maintenance from day to day are due, physical science tells them nothing inconsistent with this belief. If failure to find any sustaining virtue in matter and motion is evidence of an external sustaining power, physical science affords this evidence; but no one who admits this can hope to escape calumny; although it seems clear that the man of science is right, . . . for refusing to admit that he knows the laws of physical nature in any way except as observed order.
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> Many will, no doubt, receive with incredulity the assertion that the ultimate establishment of mechanical conceptions of life has no bearing, either positively or negatively, upon the validity of such beliefs as the doctrine of immortality, for example. The opinion that life may be deducible from the properties of protoplasm has, by almost universal consent, been held to involve the admission that the destruction of the living organism is, of *necessity,* the annihilation of life. Yet it seems clear that this deduction is utterly baseless and unscientific; . . . if it be admitted that we find in nature no reason why events should occur together except the fact that they do, is it not clear that we can give no reason why life and protoplasm should be associated except the fact that they are? And is it not equally clear that this is no reason why they may not exist separately?

During his first years at the Johns Hopkins University he and other members of the biological department boarded at "Brightside," on the shore of Lake Roland, seven miles from Baltimore. Here he met his future wife, Amelia Katharine Schultz, to whom he was married June 13, 1878. In after years Mrs. Posey, owner of "Brightside," bequeathed this beautiful estate to her favorite niece, Mrs. Brooks. Here Doctor Brooks and his family lived a happy life, with books, greenhouse, garden, and trees; and here Doctor and Mrs. Brooks entertained repeatedly the graduate students of the biological department. All of these students remember Doctor Brooks' devotion to Mrs. Brooks and the children. His interest in the education of his children and his pride in their achievements were so great that he not infrequently spoke of these things to his students, and his complete devotion to Mrs. Brooks was both touching and beautiful. For several years before her death Mrs. Brooks was an invalid, and Professor Brooks frequently spent days and nights at her bedside reading to her and attempting to ease her suffering, and no other work or duty was allowed to interfere with this service of love. Mrs. Brooks was a woman of simple and charming personality, and one of the most delightful memories which zoological students have of their life in Baltimore is of the pleasant evenings spent with Professor and Mrs. Brooks at their home, when biological classics were read and discussed, when the various biological expeditions were talked of, and in lighter vein, when the sayings of the children were told, the animal pets shown, and the home-grown orchids exhibited. No one who experienced it can ever forget the simple and cordial hospitality of Professor and Mrs. Brooks, nor the sense of deep and abiding happiness which these glimpses of their home life gave.

Professor Brooks was a man of wide culture, though his absorption in his work was so great that many knew him only as a naturalist. He read widely, and wrote with much attention to his style. He knew well the world's best literature and art, and in his later years he found that he had a strong liking for music, especially the great compositions of Beethoven, Mozart, Wagner, and Bach.

One of his strongest characteristics was his judicial and philosophical temper. When he was once asked if he did not fear that someone would anticipate him in his great work on Salpa, on which he had worked for many years, he said: "I long since ceased to be troubled by such thoughts, for if another should publish on this or any other subject before I do, his work would probably be better or worse than mine. If it was better, I should be glad to be saved the mortification of having published poorer work; if worse, it would only afford additional material for my paper." His mind was too large for little things, too sane for foolish ones. He was remarkably original and suggestive in his methods of thought, and in his views of scientific, social, and philosophical problems he was as artless and direct as a child. He was critical, yet tolerant; modest, but dignified; loyal to his friends, his university, and his ideals; independent in thought and action, and not easily moved from a position he had once taken. He was kind and gentle; and neither in his publications nor in his relations with students did he ever deal in scorn, irony, nor invective. President Remsen said that he had been called the most lovable man in his faculty.

What is the secret of his remarkable influence over others, which his students and associates recognize? By general consent it is attributed not merely to his greatness as an investigator and teacher, but also to his character as a man. In his life there was nothing either to be concealed or explained. He was "a man in whom there was no guile;" a man of such transparent simplicity and sincerity, of such single-hearted devotion to science, so simple-minded, natural, kind, gentle, pure in thought and deed, that his *life* as well as his *work* has left an indelible impression upon all who knew him.

SICKNESS, DEATH, AND BURIAL.

A congenital defect of the heart had caused him to lead a less active life physically than do most men, and to this trouble other bodily ills were added as life advanced. He bore all these ills with fortitude and patience, and many of his friends did not know how serious his condition was. Professor Andrews, who was closely associated with him, says:

> In 1908 difficulty in breathing added to his burdens and his machinery was most seriously out of order. He continued to come to his lectures and worked earnestly to complete a final paper on salpa, for which the drawings were finished and which he planned to write out in the summer. This, he said, would probably be his last piece of serious microscopic research, since trouble with his eyes made the employment of immersion lenses too difficult; and his mind was eager to digest the facts of his long experience and the recent work of others. But his strength

was not equal to the task. Sudden attacks confined him to his home, but yet his will brought him back to his laboratory, till one last day, February 12. After preparatory rest, driven by his conscientiousness, he forced himself to attend an oral examination of a candidate for the degree of Ph. D. Then walking to the train that brought him home, he was there overcome by a serious collapse. He was persuaded to go to the hospital and, after most severe attacks there, rallied; but in nine long months that followed he scarcely left his wheel-chair.

When he returned to his home he got such comfort as might be from the advent of spring, the passing of summer and the long lingering of autumn, amidst scenes so familiar and dear. Despite his critical state he was deeply interested in such news as came to him from the University. His last official act was a strong, successful plea for another when his own interests might well have absorbed his attention. His was real friendship growing out of his own wide sympathies.

While having some strength to correct the proofs of papers in press, he felt most keenly his inability to put his last work upon paper, and till this work was done he would not deem it right to retire or seek a pension.

Professor Brooks once told the writer of this memoir that he proposed to retire from his professorship when he had reached the age of sixty, and thereafter devote himself entirely to philosophical and scientific work. He reached the age of sixty in March, 1908, but how different was his realization from his plan. His retirement was not to the scholarly leisure for which he longed, but to pain, weakness, and mortal sickness. For nine months he struggled against a complication of organic heart trouble and kidney disease; he was unable to walk or lie down, but lived in a reclining chair. For a month before his death he was often in a semi-comatose condition, and for the last three or four days was unconscious. The end came at last at sunrise on Thursday, November 12, 1908.

The autopsy revealed chronic diffuse nephritis, arteriosclerosis, congenital malformation of the heart with open septum ventriculorum, cardiac hypertrophy, atrophy of the olfactory lobes, and atrophy of the cerebral cortex. The heart was enormously enlarged, and with the opening in the septum between the two ventricles it is surprising that he lived as long as he did. He had for years expected death at any time, and at forty congratulated himself on having lived so much longer than any one acquainted with his condition could have expected. It is the opinion of experts that the explanation of his living to such a comparatively good old age, was due to the fact that the heart lesion was very well guarded by muscular tissue, so that it did not increase during life. Had it been otherwise, it would have been out of the question for him to have survived so long.

His funeral was held on November 16th, at Towson, Maryland. After preliminary services in Trinity Church, his body was followed by his colleagues, students, and friends to its last resting place "on the brow of a hill overlooking a broad valley, in the cemetery of the county seat of Baltimore county."

A meeting commemorative of Professor Brooks was held at McCoy Hall, Johns Hopkins University, on Sunday afternoon, December 6, 1908. President Remsen presided, and spoke of Doctor Brooks' early connection with the university, and of his career as an investigator, a teacher, a colleague, and a man. Addresses were delivered by Prof. B. L. Gildersleeve, Dr. H. M. Hurd, Prof. W. H. Howell, Prof. E. A. Andrews, and Dr. Caswell Grave. These addresses, together with a letter from Prof. William Hand Browne, and a biographical sketch of Professor Brooks by Doctor Andrews, were published in the Johns Hopkins University Circular for January, 1909.

A memorial dinner, attended by former students and biological associates of Professor Brooks, was held in McCoy Hall, Johns Hopkins University, on the evening of December 31, 1908. About sixty persons were present, and short addresses were made by Profs. S. F. Clarke, of Williams College; E. A. Birge, of the University of Wisconsin; E. B. Wilson and T. H. Morgan, of Columbia University; H. W. Conn, of Wesleyan University; H. H. Donaldson, of the Wistar Institute; C. F. Hodge, of Clark University; F. H. Herrick, of Western Reserve University; M. M. Metcalf, of Oberlin College; J. P. McMurrich, of the University of Toronto; H. V. Wilson, of the University of North Carolina; R. G. Harrison, of Yale University; E. G. Conklin, of Princeton University, and W. H. Howell and E. A. Andrews, of Johns Hopkins University.

At this dinner it was decided to publish a memorial volume to Professor Brooks, to consist in the main of original scientific papers contributed by his pupils. Since Doctor Brooks was one of the editors of the Journal of Experimental Zoology, it was decided to publish this memorial as a volume in that series; and it is now in course of preparation. In what better way may the memory of a great scientist and teacher be honored than by carrying forward the torch which has fallen from his hand?

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* Professor Brooks made no list of his publications and the following list has been compiled from many sources and may not be entirely complete. I am particularly indebted to Professor Andrews for assistance in preparing this list.

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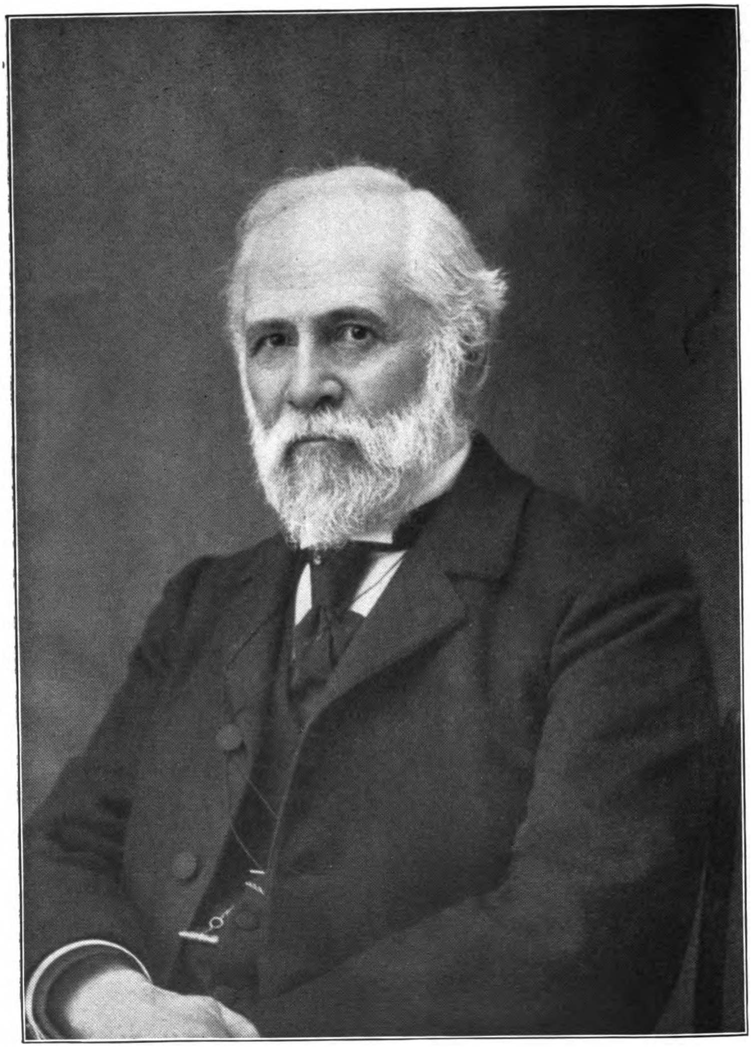

Yours Sincerely
C. A. Young

UNIV. OF ICH.

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BIOGRAPHICAL MEMOIR

OF

CHARLES AUGUSTUS YOUNG

1834-1908

BY

EDWIN B. FROST

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CHARLES AUGUSTUS YOUNG.

Charles Augustus Young was born in Hanover, New Hampshire, the seat of Dartmouth College, on December 15, 1834, and he died seventy-three years later, on January 3, 1908, in the same village, which had thrice been his home—in youth, in early manhood, and after his retirement from active work. An academic career was his by inheritance, for his maternal grandfather, Ebenezer Adams, of New Hampshire origin, was professor of mathematics and natural philosophy at Dartmouth from 1810 to 1833, and was succeeded in that chair by his son-in-law, Ira Young, father of Charles Augustus. Ira Young was also from New Hampshire, having been born at Lebanon, five miles from the college, in 1801. He was prevented by circumstances from entering college until after he was of age, but he took high rank and graduated in 1828, returning to the college two years later as tutor, and then assuming the duties of professor in 1833. Five years later his chair was changed to that of natural philosophy and astronomy, and it was filled by him with distinguished success until he died, in 1858. He was survived for thirty years by his widow, Eliza Adams, a woman of strong character and intellect.

Charles Augustus thus grew up in the atmosphere of natural philosophy, and, gifted with an active mind, he was ready for college before he had reached his fourteenth birthday; but it was thought best by his father that he should delay his entrance for a year. He graduated in the summer of 1853, at eighteen and a half years, the leader of a class of about fifty men. From his early youth he assisted his father in some of his scientific duties, and made with him a trip to Europe in the summer of 1853, when the elder Young went abroad to examine foreign observatories and to secure instruments for the Shattuck Observatory, then in process of establishment, largely through his own efforts. For two years after graduation Charles taught the classics in the well-known preparatory school, Phillips Academy, at Andover, Massachusetts. During the next year he studied in the theological seminary at Andover, in accordance with an early plan to become a missionary; for a part of the year he continued his instruction in the classics at the academy. His later writings show that this training in the classics stood him in good stead.

An invitation to become professor of mathematics, natural philosophy, and astronomy at the Western Reserve College, at Hudson, Ohio, now changed his career, fortunately for science. He entered upon the numerous duties of his new position at the beginning of 1857, and for nine years devoted himself to this work of teaching, with little opportunity and presumably with little apparatus for research. He established a time-service for the neighboring city of Cleveland, but it does not appear that he made astronomical observations to any considerable extent. During several summer vacations at this time he acted as astronomical assistant on the Government's lake survey, being chiefly engaged in telegraphic determinations of longitude.

In the summer of 1857, shortly after he began his work at Hudson, he was married at Concord, New Hampshire, to Miss Augusta S. Mixer. She was a woman of unusually gentle disposition and character, understanding well how to enliven her husband when he was depressed with his many cares and responsibilities. This singularly happy union continued for nearly forty-four years, until broken by her death in 1901. Their children, a daughter and two sons, were born while they lived at Hudson.

In 1862 he left his college duties, in prompt response to the call of the Governor of Ohio for volunteers, and was for four months captain in the 85th regiment of Ohio, his company, B, being chiefly constituted from the students of the college. The company did not see actual service in battle, but was detailed to duty in guarding prisoners, and later escorted a large number of prisoners to Vicksburg to be exchanged. Professor Young's health was somewhat impaired by these patriotic services.

In February, 1866, he accepted the call to the professorship of natural philosophy and astronomy at Dartmouth, thus succeeding his father after a lapse of eight years. This particular chair had been sufficiently endowed so that quite a large collection of apparatus, particularly in optics, had been acquired for lecture use. Fortunately for the teacher, the method of laboratory instruction had not at that time been introduced in America; otherwise he could hardly have found time for the researches which marked the next few years, and established his position as a leader in the rapidly developing branch of solar physics.

His published writings on this topic began, so far as known, with a series entitled "Spectroscopic Notes," published in the Journal of the Franklin Institute, the first of which was dated July 19, 1869. He was provided with a spectroscope having five prisms of 45° attached to a four-inch telescope equatorially mounted. With this he carefully studied the spectrum of the chromosphere, and watched with a natural interest the strange forms of the prominences, the method for observing which had been simultaneously announced by Lockyer and by Janssen only in the year preceding. These spectroscopic notes were eight in number, the last dated November, 1870. They are brief and to the point. The second recorded drawings of the prominences, and the third was accompanied by a quite satisfactory lithographic reproduction of ten sketches, which have since been widely copied. He refers in the second to his first observation of the bright lines of the chromosphere extending in upon the disk. In the fourth he describes his first study of the spectrum of a sun-spot, finding the *C* and *F* lines reversed and many lines widened, as had been recorded by Lockyer. Young expresses his surprise at the prominence of the lines of titanium in the spot spectrum, which was also true of certain calcium lines. On September 22, 1870, he saw the sodium lines D_1 and D_2 reversed in the umbral spectrum. He adds,

> "At the same time the *C* and *F* lines were also reversed, but with the great dispersive power of my new spectroscope I see this so often in the solar spots that it has ceased to be remarkable."

Two days after he sent this communication to the editor of the Journal of the Franklin Institute, he wrote again announcing his success in obtaining a photograph of protuberances on the sun's limb, using "the hydrogen line near *G*" ($H\gamma$). A woodcut was made from the photograph, but, with the modesty which was always characteristic of him, he says:

> "As a picture the little thing amounts to nothing because the unsteadiness of the air and the maladjustment of the polar axis of the equatorial caused the image to shift its place slightly during the long exposure of three and a half minutes which was required, thus destroying all the details. Still, the double-headed form of the prominence is evident, and the possibility of taking such photographs is established."

This was the first photograph of a prominence obtained anywhere, and it prepared the way for the developments which have made the photography of the prominences a daily routine at observatories concerned with the sun.

He describes in his fifth note the new form of spectroscope he designed for solar work, having the dispersive power of thirteen prisms, the light passing first through the lower portion, and then back through the upper portion of a train of six prisms. The apparatus was made by Alvan Clark and Sons, and Professor Young expresses his admiration "for the exquisite workmanship of the 43 different surfaces by which the light is either refracted or reflected on its way from the slit of the collimator to the eye." The writer can add his testimony to the delight in the use of the same instrument, practically unchanged, nearly twenty years later, and it is still of excellent service despite the improvements of spectroscopes with the general application of the diffraction grating.

His final spectroscopic note gives in a dozen pages an admirable statement "on the construction, arrangement and best proportions of the instrument with reference to its efficiency." The advantages of using a half-prism at the beginning of a train is pointed out, and a simple form of chemical spectroscope is proposed in which flint half-prisms are cemented directly to the single crown lenses of collimator and observing telescopes, the back surface of the prism being made concave to fit the lens. The plan is a very good one and has recently been applied in celestial spectroscopes.

With keen interest in the study of the chromosphere and prominences, stimulated and made possible by the far-reaching results of the spectroscopic observations of the solar eclipse of 1868, it was natural that Young should wish to observe the eclipse of August 7, 1869. He became a member of the party organized by the U. S. Naval Observatory, under the charge of Professor J. H. C. Coffin, of the Nautical Almanac Office. The station was at Burlington, Iowa, and was favored by fine weather, so that excellent results were secured. An interesting popular account of this eclipse was contributed by Professor Young to "The Dartmouth," the students' paper, for September. His scientific discussion was printed in Silliman's Journal for September, 1869, under the title, "On a new method of observing contacts at the sun's limb, and on other spectroscopic observations during the recent eclipse." Half an hour before totality he conceived the idea of observing the contact through the spectroscope set radially upon the sun's disk, and watching the bright *C* line shorten under the approach of the moon; he was gratified at the realization of his plan, and he felt confident that his observed time of contact must be accurate within a second. He suggested the application of the method to the case of the transit of Venus of 1874, for which preparations were already in mind. He later found that this proposal had been made to the French Academy by Faye in January of that year. Young examined during the totality the spectrum of prominences which he had located earlier in the day: *C* was brilliant, the next to it was "the orange line, which for convenience I will call D_3." Then he noted that the line 1474 *K* extended clear across the spectrum, and persisted when the slit was moved away from the protuberance. "Thus it was evident," he states, "that this line belonged, not to the spectrum of the protuberance, but to that of the corona." He also noted a faint continuous spectrum, without dark lines, "evidently due to the corona." The apparent coincidence of three coronal lines with lines located by Winlock in the spectrum of the aurora led Young to entertain the view that the phenomena of corona and aurora were related, with 1474 *K* in particular present in both. He did not assert the relationship with any positiveness, stating, "I do not feel in a position to urge it strongly, but rather await developments." Although he soon saw the error, it was long before it could be suppressed, after once gaining currency. There was much discussion as to the origin of the characteristic corona line 1474 *K*, Lockyer regarding it as due to iron, Secchi as due to hydrogen. The matter was not really cleared up until the Indian eclipse of 1898, when both Lockyer and Campbell found that the wave-length of the corona line is actually a trifle less (λ 5304 on Rowland's scale) than 1474 *K* (λ 5317). The latter is, as Young found, a characteristic chromospheric line, and is probably due to iron.

In view of the interesting discoveries at this eclipse it is not surprising that a strong party of American observers, under Professor Winlock, including Professors Langley, Pickering, and Young, was prepared to study the phenomena of the eclipse of December 22, 1870, at Jerez, in Spain. Better favored than most other parties, they had a chance for observations at totality, through a break in the clouds. Young's discovery of the 1474 line as due to the corona was fully confirmed; it was followed out beyond the limb a distance of more than half the solar radius, and it was seen to be the brightest of the lines. Let us now quote from Young's own words:

> "No new lines were observed with which I was not before familiar. But just at the commencement of the totality I made an observation, which was wonderfully beautiful to see, and which, I think, has important theoretical bearings. The slit of my spectroscope was placed tangential to the sun's limb, just at the base of the chromosphere, the 1474 line on the cross-wires. As the crescent of the sun (or decrescent, rather) grew narrower, this line, and the magnesium lines close by, as well as some others in the same neighborhood which I am accustomed to see bright in prominences, gradually increased in brilliancy, when suddenly, as the last ray of the solar photosphere was stopped out by the moon, the whole field of view was filled with countless bright lines—every single dark line of the ordinary spectrum, so far as I could judge in a moment, was reversed, and continued so for perhaps a second and a half, when they faded out, leaving only those I had at first been watching. This points to an atmosphere of heated vapor some five or six hundred miles in thickness above the photosphere, and tends to make Kirchhoff's original theory of the constitution of the solar surface again tenable."

This is from his interesting account of the eclipse written on the next day for the college paper, "The Dartmouth," to which he had previously contributed an exceedingly readable narration of his visits en route at Gibraltar and Tangier. In his letter to Professor Morton for the Journal of the Franklin

Institute, also written on December 23, he states his discovery of the reversing layer very clearly:

> "But the most interesting spectroscopic observation of the eclipse appears to me to be the ascertaining, at the base of the chromosphere, and, of course, in immediate contact with the photosphere, of a thin layer, in whose spectrum *the dark lines of the ordinary solar spectrum are all reversed.*"

The phenomenon was also seen, for an instant only, by Mr. Pye, a young Englishman, who assisted Professor Young, using one of his spectroscopes.

The objective reality of this phenomenon was not fully confirmed until Mr. Shackleton, of Sir Norman Lockyer's party at Nova Zembla, a quarter of a century later, obtained the first successful photograph of the "flash spectrum" at the eclipse of August 9, 1896. Since then it has been photographed by many observers at most of the eclipses favored with clear skies.

The problem of the solar corona occupied Professor Young's mind for some time after the eclipse, and in May, 1871, he published in the American Journal of Science a paper "On the solar corona," supplemented by a note on its spectrum in the July number. After the lapse of nearly forty years there is little to be added to his presentation of the complex nature of the spectrum and the probable sources of its constituents.

In 1870 Professor Young was a member of the Board of Visitors to the U. S. Military Academy at West Point, and, as secretary of the board, wrote its report to the Secretary of War.

A lecture delivered by Professor Young before the Yale Scientific Club, on "The sun and the phenomena of its atmosphere," was published as a booklet in duodecimo form of 55 pages in 1872. It probably was not widely circulated, but it formed the basis of his classic, "The Sun," of the International Scientific Series, which appeared in 1881.

His observational activities were still chiefly directed to the sun, although he printed in The American Journal of Science, in 1870, an account of "a new method of determining the level-error of the axis of a meridian instrument"; and of observations of the spectrum of Encke's comet, which was faintly visible to the naked eye in December, 1871. At this time he had a 9.4-inch Clark equatorial for his work. The observations of the cometary spectrum were consistent and reliable, and could hardly be improved upon today with the same telescope and the visual method.

Four weeks of work in the autumn of 1871, nearly at the time of a solar maximum, sufficed for a preliminary catalogue of the bright lines he saw in the spectrum of the chromosphere, 103 in number. He called attention to the presence of titanium lines, which constituted one-fifth of the whole number reversed. The advantage of a high elevation, with diminished reflection from our atmosphere, was apparent, and in the summer of 1872 Professor Young, under the auspices of the U. S. Coast Survey, made an expedition to Sherman, Wyoming, on a high plateau about 8,300 feet above sea-level, where he set up his telescope and spectroscope and added 170 to his list of chromospheric lines. He states that the elevation gave

> "even greater advantages for my special work than had really been expected, although I was never quite able to realize my *hope* of seeing all the Fraunhofer lines reversed, unless once or twice for a moment, during some unusual disturbances of the solar surface. Everything I saw, however, confirmed my belief that the origin of the dark lines is at the base of the chromosphere, and that the ability to see them all reversed at any moment depends merely upon instrumental power and atmospheric conditions." *

An observation very important in its bearing upon the future development of the study of the surface of the sun is mentioned at the end of this brief paper. Referring to the fact that the calcium lines *H* and *K* were both reversed, as constantly as *h* or *C* when the seeing was good, he adds:

> "They were also found to be regularly reversed upon the body of the sun itself, in the *penumbra and immediate neighborhood of every important spot.*" (Italics his.)

Professor Young made a comparison of the solar outbursts observed at Sherman with the magnetic records at Greenwich and Stonyhurst, and regarded it as probable that every solar disturbance receives an immediate response from the earth, and that the magnetic impulse travels, sensibly, with the velocity of light. It is surprising that this question is still under discussion after every case of marked "earth currents" or an extra brilliant aurora: the probabilities are perhaps as much in accord with Young's view as ever.

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* This has now been practically realized at the Mt. Wilson Solar Observatory. See the paper by Hale and Adams entitled "Photography of the 'flash' spectrum without an eclipse," *Astrophysical Journal,* Vol. XXX, 1909 (October), p. 222.

The coming transit of Venus was now exciting the interest of astronomers. Professor Young was asked to take charge of a party to be stationed at Kerguelen Island, but was unable to leave his teaching for the necessary length of time. He did, however, join the party under Prof. J. C. Watson at Peking, which secured results satisfactory at the time, before the comparative futility of that mode of determining the sun's distance was appreciated.

At about this time Professor Young contributed semi-popular articles on solar phenomena to the Popular Science Monthly and other serious reviews, and wrote for Johnson's Cyclopædia the articles on "Sun" and "Spectroscope." It must be remembered that during all of these years at Dartmouth he was teaching physics as well as astronomy to every third-year student in the college, and was giving annual courses of lectures at two or more schools for young women, besides many popular addresses.

He had promptly appreciated the advantages of the diffraction grating when he saw those ruled by Rutherford, who later placed some at his disposal. He then detected the duplicity of the 1474 line, thus apparently clearing up the outstanding difficulty as to the origin of the corona line, which he never could accept as an iron line. In the summer of 1876, with a good grating, he applied Doppler's principle to the rotation of the sun, and obtained the first good quantitative results by the method.* He hoped to use the atmospheric lines as reference points, but found those he tried "too faint and shadowy;" he therefore set his wires alternately upon the east and west limbs of the sun, and measured the differences, obtaining for the velocity of the sun's rotation 1.42 miles per second, while the value derived from observations of sun-spots was 1.25.

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*Vogel had sucessfully made the experiment in 1871 with small dispersion, but his results could not be very accurate quantitatively.

In the summer of 1877 Professor Young accepted a call to the professorship of astronomy at Princeton, with the assurance of a fine modern equipment and less time required for the class-room. His special appreciation of instruments and his well-balanced judgment as a teacher contributed to the establishment within a short time of the best astronomical observatory for the purposes of instruction then existing. By 1882 the excellent 23-inch Clark refractor was set up in the Halsted observatory, and provided with a powerful solar spectroscope for his own researches. But in spite of the energy necessarily required for this new construction, Professor Young was active in research as well as writing. In 1878 he conducted a Princeton party to Denver to observe the eclipse of July 29. It was the plan to investigate the spectrum of the corona and chromosphere, especially in the infra-red and ultra-violet, but the results, at this time of minimum solar activity, were less than had been expected, although the day was fine; the corona line and others were far less conspicuous than at eclipses during a solar maximum.

In the following year he made quite an extensive series of micrometric measures of the polar and equatorial diameters of Mars, using the excellent 9½-inch equatorial; the satellites were frequently seen with that instrument. Cometary spectra were also observed as they presented themselves in sufficient brightness, including Brorsen's (1879), Hartwig's (1880), and the great comets of 1881 and 1882.

The latitude and longitude of the students' observatory were carefully determined at about this time.

Professor Young contributed a number of admirable essays to the Princeton Review, having for their topics "The Recent Solar Eclipse," "Recent Progress in Solar Astronomy," "Practical Uses of Electricity," "Astronomical Facts and Fancies for Philosophical Thinkers," the last a lecture delivered before the Summer School of Christian Philosophy. All of these deserved a wider circulation than they probably received.

An extended program for the transit of Venus on December 6, 1882, was carried out under somewhat unfavorable conditions at Princeton, micrometric, spectroscopic, and photographic observations being included.

Professor Young contributed to the American Journal of Science two further papers, entitled "Spectroscopic Notes," in November, 1880, and November, 1883. Though brief, they are important. The first deals with the *H* line in the chromosphere; with the successful resolution of lines given on maps as common to two different elements ("basic lines"); with the distortion of solar prominences in a diffraction grating spectroscope, and deriving the formula therefor; he adds a note on an immense prominence, over 350,000 miles high. The second paper gives results with a powerful spectroscope of the Littrow type attached to the 23-inch telescope, whereby he resolved "the spot spectrum into a congeries of fine (dark) lines," an observation which has been fully confirmed with yet more powerful apparatus.

In 1892, when the Halsted Observatory received its new spectroscope by Brashear with a fine Rowland grating, Professor Young undertook the work of revising his list of chromospheric lines. Ill health and other causes delayed the work, so that it was never entirely completed, but it was published as "a partial revision" in 1894 in the edition in English of Scheiner's "Astronomical Spectroscopy." This was his last extensive piece of observational work on the sun. His other observations with the 23-inch telescope dealt with the planets, with certain double stars, and with the spectrum of *Nova Aurigæ*. He had at this time some exchange of opinion with a prominent English observer on the subject of large versus small telescopes. Admitting as "sadly true" the greater susceptibility of large instruments to atmospheric disturbances, he finds it also true—

> "that I can almost always see with the 23-inch everything I can see with the 9½-inch under the same atmospheric conditions, and see it better—if the seeing is bad, only a little better; if good, immensely better . . . Under higher powers, also, markings which are conspicuous with lower ones often disappear in the same way that the naked-eye markings on the moon vanish in the telescope. Most commonly, however, when I have failed to see with the large instrument anything I supposed I saw with the smaller, it has turned out on examination that the larger instrument was right, and that imagination had constructed a story that was not true, by building up faintly visible details and hazy suggestions furnished by the smaller lens."

A beginning was made in stellar spectrographic work with the new instrument, using both a grating and prisms, but attacks of sciatica had reduced Professor Young's capacity for prolonged night work, and the lack of a regular research assistant at the Halsted Observatory prevented a continuance of investigations in the field.

Solar eclipses very naturally retained his interest and he was enabled by the generosity of friends to take a small party to Russia for the eclipse of August 19, 1887. The station selected by Professor Struve for this party was not very far from Moscow, but, like most other points along the track of totality, it suffered from very bad weather, and no observations were possible. However, the trip gave Professor Young an opportunity to visit the leading observatories of Europe, renewing many friendships and establishing new ones, and he gave a very interesting account of it in Scribner's Magazine for July, 1888, under the caption, "An astronomer's summer trip."

At the eclipse of May 28, 1900, Professor Young organized quite a large party from Princeton and established a station at Wadesboro, North Carolina. The weather was very favorable and excellent results were obtained, but the corona line was too faint for carrying out the program Professor Young had prepared.

During these years Professor Young was delivering many addresses, and he always took such responsibilities very seriously—unnecessarily so, indeed, in later life. A lecture upon a topic somewhat out of his regular line would often lie heavily upon him for weeks until satisfactorily worked out. His address as vice-president of Section A at the Buffalo meeting of the American Association for the Advancement of Science, in 1876, was upon the topic "American Astronomy: its history, present state, needs, and prospects"; as retiring president of the association, at the Philadelphia meeting, in 1884, he discussed "Pending Problems in Astronomy" in a masterly fashion.

He felt no shame in accurately popularizing science, and responded frequently to the requests of the editors of the magazines. To the North American Review he contributed articles upon such topics as "Astronomical collisions," "Theories regarding the sun's corona," "The newest telescope"; to the Forum, "College athletic sports," "Great telescopes," "The latest astronomical news." He summarized the advances from 1876 to 1886 in "Ten years' progress in astronomy," read before the New York Academy of Sciences. He delivered the principal address at the dedication of the Kenwood Observatory, at Chicago, in 1891. He contributed many brief notes to the New York Independent, and wrote many reviews for that weekly and for The Critic. He also occasionally wrote at the request of the editors of New York newspapers, which did not at that time crave sensational articles so much as now. Probably the financial stress, so familiar (and perhaps ultimately beneficial) in the experience of college teachers, was also a partial motive for some of these contributions.

He contributed for Professor Newcomb's admirable "Popular Astronomy" a statement of his views upon the constitution of the sun, and, at the request of Professor Vogel, editor of the third German edition of that work, he revised that statement to correspond with the increase of our knowledge up to 1904. This was also printed in English in the magazine "Popular Astronomy."

In 1884, in conjunction with Prof. E. C. Pickering, he edited for the Proceedings of the American Academy of Arts and Sciences the researches of the late Dr. Henry Draper on astronomical spectrum-photography.

Professor Young's reputation as an author, already well established by his many semi-popular articles, was widened still more on the appearance, in 1881, of his book, "The Sun," which at once took a commanding place among works of its class. While it is a volume constantly needed by specialists in solar physics, it is written in such a simple and interesting manner as to attract and hold the intelligent general reader. It has passed through several editions, and has been translated into foreign languages.

His rare experience as a teacher was finally crystallized in his "General Astronomy," which appeared in 1888, and was widely adopted in college use. It emphasized one of his fundamental pedagogical principles, that the things taught "must be correct and accurate as far as they go." It contains ideas suggestive to the investigator, as well as teacher and student, and did much to encourage accurate thinking on the part of pupils who have studied it. The successive issues of the book were altered and enlarged by notes until a revised edition was necessary in 1898. Nearly 30,000 copies of this work have been printed. It called, however, for some rather difficult thinking for students not specializing in science, and a more elementary book, entitled "The Elements of Astronomy" (with Uranography), appeared shortly thereafter and was used still more widely in schools and colleges. Responding to the demand for a work available for quite young pupils, the "Lessons in Astronomy" appeared in 1891, and over 60,000 copies have been sold. A text-book intermediate between the "General Astronomy" and the "Elements" was called for, and was issued in 1902 under the title of "Manual of Astronomy." It was a handsomer book than the "General" and omits little of importance that is contained in the latter. An edition, revised by his niece, Miss Anne S. Young, professor of astronomy in Mount Holyoke College, is now appearing.

The very considerable labor involved in the preparation of these text-books was not given at the expense of research, as the condition of his health had prevented him from much observing after the early nineties. By a strict regimen he kept in check the inroads of a very serious disease, from which his physician could pronounce him as practically recovered only a very short time before his death.

His influence as a teacher was greatly widened by the large use of his text-books, and the position of authority which they gave him carried with it the burden of an increasing correspondence and the answering of many queries from all sorts of readers. He was also consulted very generally by teachers planning new equipment, by young men undertaking spectroscopic work, and by the many who valued his scientific and educational experience.

Upon the establishment, in 1895, of the Astrophysical Journal he became a member of its advisory board, known at first as associate editors, later as collaborators, and he retained this connection until his death.

Insufficient allusion has been made to Professor Young's appreciation for and skill in mechanical matters. He devised an improved clock escapement which has performed satisfactorily for many years at Princeton, and a suggestion of his is incorporated in most of the conical pendulum driving clocks in use in this country. In practical astronomy he would have made more contributions had his time not been occupied with solar physics; but he proposed a method of investigating pivot errors, detected the serious effect of flexure in the "broken transit," and showed how it could be corrected, and investigated in his own way the color-correction of achromatic object-glasses. He also wrote on such physical topics as "Mr. Edison's dynamometer, dynamo-machine, and lamp," and he kept abreast with the new discoveries of physics and related branches of science.

Professor Young's personal characteristics were so obvious that it is hardly necessary to allude to them in addressing his contemporaries in the National Academy; to those who have missed the great opportunity of knowing him, it may be said that he was thoroughly infused with the true scientific spirit—ever ready to modify theory to accord with newly discovered facts, and to accept the revision of what were once the best data available as new information was obtained by experiment and observation. He was entirely free from the dogmatism that often grows upon men after they have long been looked up to as authorities upon a subject. His modesty, even humility, in the consideration of the great laws of nature was a true characteristic of his greatness. This impressed itself upon his thousands of students and upon the many auditors at his lectures. As a teacher, his methods and manner were simple and straightforward; his remarks were enlivened by a quaint humor which also pervades his writings. He took a genuine interest in his pupils, and it was remarkable how quickly he learned and retained the names of the members of the large classes which always attended his courses, attracted probably less by the subject than by the teacher, who was affectionately nicknamed "Twinkle."

Professor Young was small of stature, growing a trifle stout in later life; he was not especially fond of physical exercise and had no hobbies in the way of recreation, but he took a real interest in college sports. The writer has a very distinct mental picture of him in the early seventies, playing on his well-kept lawn the then popular game of croquet, for which several of his colleagues regularly gathered. He always aimed at skill in whatever he undertook. At Princeton he found recreation in whist, playing a good hand of an occasional evening.

The life in his home was ideal, and its gentle courtesy is remembered by the many who were welcomed to its cheer. Astronomers from foreign countries, traveling in America, always included a visit to Princeton in their itinerary when possible, of course far more to see the man than the excellent observatories under his charge.

Mrs. Young was a singularly attractive woman, who playfully diverted her husband's mind from his work when he was off duty, and by her devotion to him and attention to household details, gave him the opportunity for performing his many duties with as little disturbance as possible. Her failing health greatly depressed him, and her death in 1901 was a blow from which he could not recover. Other serious anxieties and sorrows came to him before this: the dangerous accident to his oldest son from an electric shock, causing paralysis from which recovery was long doubtful and never complete; the death of his daughter's husband, Prof. Hiram A. Hitchcock, of Dartmouth, after a short married life.

Upon reaching the age of seventy, in December, 1904, Professor Young sent to the trustees of Princeton his resignation, to be effective in the following June, when his service of twenty-eight years would be completed. Evidences of appreciation of his long and useful service, and of his own personality, came to him from all directions during the remainder of the academic year, and brought much quiet satisfaction to him. He was made professor emeritus, and also came under the provisions of the retirement fund of the Carnegie Foundation.

A farewell dinner, which brought out in a striking manner the unusual feeling of regard toward him on the part of his colleagues and the university authorities, was given him on May 17, 1905, and a handsome silver loving cup was presented to him. At commencement, a month later, the degree of doctor of laws was conferred upon him at Princeton, with further expressions of deep feeling.

The poem in the New York Sun by Robert Bridges, a former pupil, gives the real spirit of his teaching:

"THE ASTRONOMER.

The destined course of whirling worlds to trace;
To plot the highways of the universe,
And hear the morning stars their songs rehearse,
And find the wandering comet in its place:
This was the triumph written in his face,
And in the gleaming eye that read the Sun
Like open book, and from the spectrum won
The secrets of immeasurable space!

But finer was his mission to impart
The joy of learning, the belief that law
Is but the shadow of the power he saw
Alike in planet and in throbbing heart—
The hope that life breaks through material bars,
The faith in something that outlives the stars!"

He returned to his early home at Hanover, where his daughter, with her son, lived with him. The enfeebled condition of his health did not permit him to undertake much work, however, and he again was afflicted by the long illness and death of his daughter. During the last months of his life he was recovering from the Bright's disease which had beset him for years, and there was hope that he might have some period of health, but after a brief attack of pneumonia he died peacefully on January 3, 1908. He was survived by two sons, Charles Ira, of the Westinghouse Electric Company, and Frederick A., of the U. S. Coast and Geodetic Survey, and by his grandson, Charles Young Hitchcock.

Many honors naturally came to him during his career. He was made associate of the American Academy of Arts and Sciences in 1869, of the Royal Astronomical Society in 1872, and later of the Philosophical Societies of Manchester and of Cambridge, England, and of the Società degli Spettroscopisti Italiani. He became a member of the National Academy of Sciences in 1872, and of the American Philosophical Society in the same year. He was made a foreign correspondent of the British Association for the Advancement of Science in 1887. In 1891 he received the Janssen medal of the French Academy of Sciences for his spectroscopic researches. Honorary degrees were bestowed upon him liberally—that of doctor of philosophy by Pennsylvania in 1870, and by Hamilton in 1871; that of doctor of laws by Wesleyan in 1876, Columbia in 1887, Western Reserve in 1893, Dartmouth in 1903, and Princeton in 1905.

Throughout his whole life Professor Young retained the strong religious convictions of his youth: he was essentially a man of faith. There is an especial appropriateness in the inscription upon his tomb in the old cemetery at Hanover:

> "For now we see through a glass, darkly; but then face to face."

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NOTE.—The portrait accompanying this memoir was taken at Princeton in April, 1897, and is the original for Harrison's painting.

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Very truly Yours B. Silliman

UNIV. OF MICH.

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PART OF VOLUME VII

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OF

SAMUEL WILLIAM JOHNSON

1830-1909

BY

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Of the biographical memoirs which are to be included in Volume VII, the following have been issued:

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23- 88:	William Keith Brooks	Edwin Grant Conklin
89-114:	Charles Augustus Young	Edwin B. Frost
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JOSEPH LEIDY.

The name of Joseph Leidy will endure both as the founder of vertebrate palæontology in America and as the last great naturalist of the old, or eighteenth and early nineteenth century type. Among zoölogists he was the last to treat of the whole animal world from the protozoa to man, rendering in every branch contributions of permanent value. From his researches among the minerals, plants, infusorians, entozoa, and mollusks, he ranged into comparative anatomy as well as into his greatest field of research, vertebrate palæontology. In the year 1852 we find him writing upon fossils from the West, the geology of the Badlands, the life history of bees, their anatomy and the physiology of their reproductive organs, as well as entering the discussion of some new fungi with an English microscopist, the specific determination of various parasites, as well as numerous plants, the investigation of some new points in comparative anatomy, the observation of the movements of some new Rhizopods. His encyclopædic knowledge, broad grasp of the whole field of natural history, precision and originality of observation in every field, present a combination of endowments which will never reappear in a single individual.

In vertebrate palæontology, Leidy's favorite field of research, all his great contributions antedate the beginnings of the work of Edward Drinker Cope and Othniel Charles Marsh, the two National Academicians whose names are always associated in our minds with his. His monograph of 1869, "On the Extinct Mammalia of Dakota and Nebraska," is, with the possible exception of Cope's "Tertiary Vertebrata," the most important palæontological work which America has produced.

ANCESTRY AND LIFE.

Descent from patriotic German-American stock enables us to understand the sources of Leidy's fine moral qualities. His remote ancestors, before 1720, were of the German peasantry. While he was chiefly of German extraction, his paternal grand-mother, Catherine Le Febre Comret, was a sister of Francis Joseph Le Febre, Duke of Dantzig, Marshal under Napoleon I.

Intellectually Leidy inherited the sterling thoroughness generally characteristic of Teutonic science, the indomitable search for knowledge and love for the plain, unvarnished statement of fact, unclouded by speculation. In following up the immediate ancestry of Joseph Leidy we find, both on the father's and mother's side, well-to-do people, tillers of the soil, partly engaged in their own tanning and pottery. We also fail to find among his more remote military forebears any anticipation of his devotion to natural science unless it be that one of his great uncles was a surgeon, and that he was of the same parent stock as the German anatomist, Prof. Franz Leydig, of Wurzburg and Bonn. Leydig was Haeckel's master in embryology; his grandfather was a brother of Joseph Leidy's grandfather. It appears that Leidy's remarkable genius as an observer was not accumulative but was suddenly born with him. Of the many aspects of his character as a man of science we will speak more definitely after reviewing his life and works.

Joseph Leidy was born in Philadelphia on the 9th of September, 1823. His father was a hatter and is described as a man endowed with practical good sense, honest and industrious, but not of any conspicuous mental force nor of very great education. He was of ample means and never deprived his family of the wherewithal for their mental development. He was desirous that his sons should live independent, self-supporting lives, and naturally became concerned when he found Joseph preparing to support himself by teaching rather than by the practice of his profession as a physician. Certain it is that Leidy did not suffer from the financial strain which so many men of science experience in early life.

Joseph Leidy's mother, Catherine Mellick, was a woman of intellect and education, a descendant of the Mellicks (Moelich), also natives of Rhenish Germany, who founded the celebrated "Old Farm" in New Jersey and later emigrated to Pennsylvania. When Leidy was only a year and a half old his mother died, leaving behind her four children, of whom Joseph was the third. His stepmother, Christiana Mellick, was also an intelligent woman, and gave Joseph his early training until he was sent to the private school of William Mann, a Methodist clergyman, where he received as good a preparatory training as Philadelphia afforded in that day. At this classical academy, where Latin and Greek formed the principal part of the instruction, Leidy did not distinguish himself in his studies, but showed an intense interest in all branches of natural history, although none of these subjects were included in the curriculum. It was his greatest delight to wander out into the rural districts of Philadelphia in quest of minerals, plants, insects, etc., and occasionally these excursions would tempt him to absent himself from school without leave. He was indifferent to boyish sports and devoted his leisure time to drawing the natural objects which he collected. A note-book has been preserved, dated 1833; it contains a series of careful drawings of snail shells and shows the degree to which Leidy, solely through his own efforts, had cultivated his natural abilities at the age of ten. In later years he became an expert draughtsman, especially of microscopic objects. When at the age of sixteen he left school his father determined that he should be an artist. His mother, however, wished her sons to "learn professions," and, as Leidy later explained, "she being the stronger carried the point."

About this time Leidy spent several months in a wholesale drugstore of a cousin physician and druggist, and soon acquired so accurate a knowledge of drugs that he was recommended to take temporary charge of a retail branch of the business; but from the skill he had already displayed in dissecting, which he had practiced on a few domestic animals, his mother believed that she saw in him the makings of a great physician and she prevailed on his father to allow him to take up the study of medicine. For a year he studied anatomy under a private teacher, Dr. James McClintock, and in 1841 he matriculated at the University of Pennsylvania. Here his chief instructor was Dr. Paul B. Goddard, who in leisure evenings at his own home introduced Leidy to the use of the microscope, which became thereafter one of the greatest pleasures of his life. In 1844 Leidy received the degree of doctor of medicine, after presenting a thesis on "The Comparative Anatomy of the Eye in Vertebrated Animals." He opened an office in Philadelphia, and for two years practiced the profession of medicine with little success. With ardent interest he continued to pursue his studies in comparative anatomy, for which his practice left him ample time, and also acted as prosector to the eminent Dr. Horner, professor of anatomy at the university.

Leidy's initial publications appeared, at the age of twenty-two, in the year 1845 in the Proceedings of the Academy of Natural Sciences of Philadelphia and of the Boston Society of Natural History, covering[a] new species of fossil shells from New Jersey,[b] the microscopic examination of a vertebra of a fossil Zeuglodon,[c] the anatomy of the snail *Helix albolabris,* the anatomy of the dart, and several species of American pneumobranchiate mollusks. This last paper, presented before the Boston Society of Natural History, showed so much ability that Leidy was immediately elected a member of the society. At this time, September, 1845, Amos Binney, president of the society, wrote him: "The value of the compliment of your election to membership in the Boston Society of Natural History consists in the wish to encourage you to continue to give some portion of your time to that branch of natural history in which there is no doubt that you may render essential service to science. I mean the comparative anatomy of the lower orders of animals."

On July 29, 1845, Leidy was also elected to membership in the Academy of Natural Sciences of Philadelphia, an important event alike in his history and that of the academy. He published the first of a long series of contributions, and for the succeeding forty-six years he exerted a most active influence on the well-being of the institution in every department, until in the world at large the names of Leidy and the academy became inseparably associated.

This recognition of the originality and breadth of Leidy's observations by the two leading scientific institutions of America truly marked the first turning point in his career. In these days when science has a recognized place in every university and school, and museum collections are available in all the large cities, it is difficult to realize how much the privileges of the academy library, apparatus, and collections, as well as the interest and coöperation of the specialists in its circle of members, could mean to the young scientist. The records of the academy show that Leidy regularly attended the weekly evening meetings from this time on and almost invariably took part in the discussions. Soon after his election as a member Leidy was appointed librarian of the academy, and performed his duties in the conscientious and efficient way in which all his work was done. In later years he served the academy as chairman of the board of curators, and finally as president for two dates.

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[a] Published in Proc. Boston Soc. Nat. Hist., 1845. (See bibliography.)

[b] Notes taken on a visit to White Pond, Warren County, New Jersey, [and a list of ten species of fossil shells collected there]. Proc. Acad. Nat. Sci. Philadelphia, vol. 2, 1845, pp. 279–281.

[c] [The microscopic examination of a portion of a vertebra of the fossil Zeuglodon shows that it has all the characteristics of recent bone.] Proc. Acad. Nat. Sci. Philadelphia, vol. 2, 1845, p. 292.

The six papers which Leidy contributed during the year 1846 cover the anatomy of the sloth and of one of the lemurs, the wings of the locust, the olfactory organs in one of the gasteropods, and include also his first two contributions to the knowledge of parasites which infest mammals.

From this early period dates Leidy's first discovery, which in a practical way has contributed more than any other to the welfare of humanity and has resulted finally in the saving of hundreds, even thousands, of lives annually. With his keen powers of observation he noticed in a piece of ham served at his breakfast table numerous minute white specks, which on examination under the microscope he recognized at once as cysts of *Trichina spiralis,* which were known to him from their occurrence in human muscles. In 1835 Richard Owen had described and named *Trichina* as parasitic in the human subject, but up to the time of Leidy's discovery no one had surmised the true source of this dangerous entozoön in man.[a]

In the summer of 1846, at the age of twenty-three, Leidy visited Samuel Stehman Haldeman, making collections of animals and plants in the vicinity of his home, reports of which appear in 1847 as his first contribution to the anatomy of marine vertebrates and invertebrates. It was at this time that through his dissections his attention was drawn to the existence of a fauna and flora within living animals, a subject which he selected for a special contribution in 1853. During the fifties he was a frequent visitor to Newport, Rhode Island, and Narraganset Bay, where much of his work on marine zoölogy was accomplished.

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[a] [On the existence of an Entozoön (*Trichina spiralis*) in the superficial part of the extensor muscles of the thigh of a hog.] Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1846, pp. 107–108.

The year 1847 is also noteworthy for the appearance of Leidy's first two contributions to vertebrate palæontology,[a] the subjects being a fossil horse of the East and a fossil cameloid of the West (*Poëbrotherium*). This marked the beginning of his interest in palæontology and of those manifold observations and notes on the extinct vertebrates of every region of North America which fill the proceedings and memoirs of the Academy of Natural Sciences. At this time Cope was seven years of age and Marsh sixteen. Although Leidy's labors throughout his life extended over almost every field of zoölogical research, the complete list of his publications shows that the study of vertebrate palæontology absorbed his energies chiefly up to the year 1873, after which his time was again devoted chiefly to microscopic organisms, although he made occasional contributions to palæontology.

In 1847–1848 Leidy definitely decided to abandon the practice of medicine and to devote himself to scientific research and teaching, whatever financial difficulties might arise or as a consequence lie in his path. He therefore accepted an appointment as demonstrator of anatomy in the Franklin Medical College, which he surrendered, however, at the end of one session in order to resume his anatomical work under Dr. Horner at the University of Pennsylvania, and at the same time to deliver privately his first course of lectures on anatomy, human and comparative. His first notable contributions in this field were those of 1847 and 1849 on the evidence of the existence of the intermaxillary bone, confirming the earlier prophecy of Goethe.

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[a] On the fossil horse of America (*Equus americanus*). Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1847, pp. 262–266.

On a new genus and species of fossil Ruminantia (*Poëbrotherium wilsoni*). Proc. Acad. Nat. Sci. Philadelphia, vol. 3, 1847, pp. 322–326.

Several contributions to human anatomy appear about this period (1848–1849), which prepared him, at the age of twenty-seven, for the editorship of the first American edition of Quain's "Human Anatomy."

The summer of 1848 was spent abroad, Dr. Horner having invited his young assistant to accompany him. In London, Paris, Vienna, and other large cities, he visited the museums and hospitals and made the acquaintance of eminent anatomists and physiologists, among others Owen, Darwin, Majendie, Milne Edwards, and Johannes Müller. Leidy sailed for London on a packet ship, and soon after arrival he wrote a letter to Richard Owen in which he used the following appropriate expression: "Looking upon you as the Cuvier of England." Owen extended to him every courtesy. He dined with Owen and met Charles Darwin just before returning to America. In Paris he found himself in the midst of the rebellion of 1848, and in a long letter to his mother, describing the exciting events, he writes: "I got between the fires."

With his vision greatly broadened by this experience, Leidy returned to his work with increased energy. He delivered a course of lectures on microscopic anatomy, published the new edition of Quain's "Human Anatomy," and began a course of lectures on physiology at the Medical Institute of Philadelphia.

Indicating that he was a pioneer in this country in his special field of microscopy is a letter received in 1852 from the Italian anatomist, Corti: "I have not been aware of any one else in America interested in microscopic anatomy, and write to interest you in my investigation of the organ of hearing." [a]

After a short time overwork threatened Leidy with serious illness, and he was obliged to suspend his teaching, as well as his investigations, for some months. In the spring of 1850, at the age of twenty-seven, a second opportunity to travel abroad presented itself. Dr. George B. Wood, who had just been appointed professor of the practice of medicine in the University of Philadelphia, and who wished to make a collection in Europe of specimens, models, and drawings for his lectures, persuaded Leidy to accompany him.

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[a] This was the only work that Corti published, as he relinquished scientific pursuits and entered the field of Italian diplomacy.

In the meantime an intimacy had sprung up with Spencer F. Baird. In 1853 Leidy wrote to Baird: "I am desirous of making a special library of vertebrate palæontology so far as my means will permit." In 1852 Leidy had arranged to accompany an expedition to the West to collect fossils. He particularly desired to enter the field, as he wished to make certain geological observations. We must consider it a great loss to science that he was unable to carry out his plan. As he was about to start Dr. Horner, professor of anatomy at the University of Philadelphia, became so seriously ill that Leidy was informed by his friends it was absolutely essential for him to remain as a substitute for Dr. Horner's course of lectures, as in the event of his death he would in all probability be called to the chair. Baird wrote to him: "Do not leave Philadelphia until you have settled the professorship," and added, "Do not worry about the fossil bones; they will all be sent to you anyhow."

It is characteristic of the dogmatic influences of the times that the rival candidate for the chair of anatomy was using Leidy's scientific researches as a weapon in opposing him. He writes to Baird: "All those things which you would think would recommend me to the trustees my opponent is using against me. I am shamefully abused as being an atheist, an infidel. It has been positively asserted that I seek to make *proselytes to infidelity,* and that in my writings I have tried to prove that geology overthrows the Mosaic account of the creation. You may judge of my feelings."

Aided by warm letters of recommendation from Wyman, Dana, and Henry, Leidy, although only thirty years of age, received the professorship of anatomy in 1853. Dana referred to him as the most eminent comparative anatomist in the country. Wyman wrote: "It may be added that Dr. Leidy is eminently distinguished as a man of science, with an ardent love of nature, with untiring industry, with quiet and accurate powers of observation. He combines a highly philosophical mind and great fidelity as a searcher after truth." Joseph Henry wrote: "If the regents, or rather the trustees, should be so blind to the best interests of the institution as to place some favorite over your head, they will repent it. If you continue to grow as you have begun, places of honor will be forced upon you."

At the age of forty, in August, 1864, Leidy married Anna Harden, of Louisville, Kentucky. They had no children.

When, in 1867, the Academy of Natural Sciences of Philadelphia was planning the erection of a new building, more ample accommodations for its growing museum and library, Leidy was appointed a member of the board of trustees of the building. The administrative duties connected with this post were little to his taste, and so far as possible he left all decisions to other members of the board, whom he considered more practical than himself.

In 1874 Leidy was offered the Hershey Professorship at Harvard. In 1875 he again went abroad, and during his visit to London he met Mrs. Huxley, Huxley himself being at the time in Edinburgh lecturing. The day following his call Leidy received a letter from Huxley, in which he expressed regret, and wrote in his characteristic way: "Mrs. Huxley once saw an iceberg, which I in all my travels never had a chance of, and I am really in despair missing all chance of seeing you. If she has also the power of boasting that she met you and I have not . . . my life will not be worth living. For domestic reasons if for no other, therefore, let me have the pleasure of seeing you."

In 1880 an invitation to lecture and supervise the studies of the graduate students of Princeton University was considered and declined.

Some of the most interesting episodes in Leidy's life may be considered in connection with his two chief lines of investigation, the protozoa and fossil vertebrates. His character and intellectual predispositions are constantly reflected in his work. His knowledge of the general facts of natural history was vast. While lecturing at Swarthmore the students would delight in trying to bring to his notice some natural object with which he might prove to be unacquainted, but they never succeeded in finding him unprepared. In scientific discussion he seemed to have an intimate and first-hand knowledge of every speciality, in addition to being a master of anatomy, invertebrate zoölogy, and palæontology. Although he did not claim to be a mineralogist his knowledge of minerals and precious stones was vast. He lectured at Swarthmore for years on minerals, and his collection of minerals, sold to the Smithsonian Institution after his death, reflected his keen powers of observation and judgment. He made one of the first collections of gems arranged in this country, to which he added from time to time until a few years before his death it was disposed of in Boston; some of these gems are now in the collection of the American Museum of Natural History of New York.[a]

Botanical studies continued to attract him. He once expressed regret at not having time to prepare a monograph on the "grasses," which interested him particularly.

Leidy's life continued to be characterized by unabated vigor and constant industry. Year after year the Proceedings of the Academy of Natural Sciences contained numerous short communications, with studies of parasitism and palæontology taking the most prominent place. In 1881 Leidy was unanimously elected president of the Academy of Natural Sciences of Philadelphia—an office which he held until his death, in 1891. When, in 1884, after almost twenty years of preparation, the University of Pennsylvania established a department of biology, Leidy was made its director, and was also appointed to fill the chair of zoölogy and comparative anatomy. In the following year the Wagner Free Institute of Science of Philadelphia elected him its president. Thus the prophet was honored in his own country, and Philadelphia may look back with satisfaction to her generous and timely recognition of the greatness of her son.

Accompanied by his wife, Leidy visited Europe for the last time in 1889. He returned home little refreshed and his strength began to fail soon afterward. Nevertheless he continued his teaching and the performance of his many duties until the week before his death.

Leidy passed away on April 30, 1891, in has sixty-eighth year, having continued his studies almost to the very last. The amount of work accomplished by him in his productive period of forty-six years (1845–1891) is extraordinary. His published writings of various lengths exceed 600 titles. Although an indefatigable worker, he was devoid of personal ambition, and seems to have sought positions not for the distinction they might bring to him, but only for the opportunity which they might afford for the pursuit of his scientific studies. He frequently placed others before himself. When invited to make the opening address of the American Museum of Natural History in New York, he declined, advising the trustees to ask Professor Marsh in his stead. To Meek and Hayden, who wrote to him in 1859 regarding credit for a geological observation, he replied: "I am too little ambitious to give myself any trouble about such a case as that you mention. Even should any one pass unnoticed more important things I may have done, I shall feel no regret about the matter."

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[a] See Memoir of Joseph Leidy by Persifor Frazer, American Geologist, January, 1892.

He cared as little for money as for position, his tastes being extremely simple. He was simple and unassuming in habit from first to last and unaffected by the honors which came to him from every part of the world. The tributes paid to Leidy at the time of his death enable us to realize in what high esteem he was held as a man. It is said that he never made an enemy; the testimony of all with whom he came in contact is that he was as lovable as he was great in character. A love of peace was one of the essential characteristics of his nature, combined with a strong passion for truth and love of the beautiful. He disliked controversy exceedingly and was reserved on all matters relating to his personal beliefs, such as religion. The Unitarian Church appealed to him most strongly. To quote from his own words: "I have always had an antipathy to enter into a discussion of religious opinions, and when persons, curious to know mine, have questioned me, to avoid discussion, I have the last few years referred them to the admirable work of John Fiske [Cosmic Philosophy]. . . . Through life I have been conscious of having been a devoted worshiper (again to quote Mr. Fiske) 'of an ever-present God, without whom not a sparrow falls to the ground'; and I have often felt annoyed at the implied reproach of infidelity from the self-sufficient who consider that they fulfill all religious duty in lip service to the same Deity." It has been alleged that he resembled Darwin in a lack of appreciation of poetry, but this appears to have arisen from a misunderstanding. Among his favorite writers were Longfellow and Holmes. "The Chambered Nautilus" of the latter had an especial charm for him. He was fond of art, and his own artistic skill was coupled with a keen delight in beauty of form and color.

CONTRIBUTIONS TO ANATOMY.

In 1854, the year after his appointment as professor, Leidy was selected to represent the University of Pennsylvania at the meeting of the American Medical Association in St. Louis.

After his appointment he came to be regarded as one of the leading authorities on anatomy in America. His elementary treatises on human anatomy,[a] published in 1861, and republished in a large and revised edition in 1889, was for many years a classic text book for students of medicine, and even now repays study, though out of date in many of its statements. It is conspicuous for clearness, simplicity, and accuracy—features which characterized all of Leidy's writings.

During the Civil War Leidy volunteered as surgeon to the Satterlee Military Hospital, which was established in West Philadelphia. The task of superintending and reporting on the autopsies was assigned to him, and in the medical and surgical history of the war, published between 1870 and 1879, are contained the accounts of sixty autopsies performed by Leidy. Although he continued to hold the professorship of anatomy throughout his life and performed the duties connected with it in a more than creditable manner, his interests gradually drew him farther and farther from the subject of anatomy. After his report to the Surgeon General of the Army he wrote only one more paper directly connected with the science of medicine. As in his school days, it became his pastime to study almost every branch of natural history, and all his leisure was devoted to varied researches, which in retrospect seem to constitute the most voluminous portions of his work.

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[a] An Elementary Treatise on Human Anatomy. J. B. Lippincott Co., Philadelphia, 1861. Second edition, rewritten. J. B. Lippincott Co., Philadelphia, 1889.

CONTRIBUTIONS TO MICROSCOPY.

Leidy's studies in helminthology continued to the last and gave him a very great reputation; specimens chiefly of parasitic worms were sent to him for determination from all parts of the United States. Some time previous to his death he had in contemplation the publication of a work upon helminthology and parasitology. In the early years of his researches in this field he was the only American naturalist who devoted any considerable time to these studies. Leidy's plan of publication was never carried out, but we are indebted to Joseph Leidy, Jr., a nephew of the great anatomist, for bringing together, in the Smithsonian Miscellaneous Collections,[a] all of Leidy's published researches in this field, beginning in September, 1846, and continuing until 1891, the last year of his life. In 1853 Leidy published his first memoir in this field, entitled "A flora and fauna within living animals," [b] a volume beautifully illustrated by ten plates from Leidy's own drawings.

His first materials for the study of the Protozoa had been gathered in the East, in the pools and streams in the neighborhood of Philadelphia. During the years 1872–1873 he spent his summers in the region of Fort Bridger, Wyoming, and when obliged for a time to abandon the subject of vertebrate palæontology, he turned again to that division of the Protozoa known as Rhizopods.

Dr. F. V. Hayden, director of the United States Geological Survey of the Territories, encouraged these researches and showed a very broad appreciation of the scope of the survey in publishing "Freshwater Rhizopods of North America" as volume 12 (1879) of the survey monographs. In introducing this monograph, Leidy observes: "During the last four years

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[a] Researches in Helminthology and Parasitology by Joseph Leidy, M. D., LL. D., professor of human and comparative anatomy and zoölogy in the University of Pennsylvania, president of the Academy of Natural Sciences, and of the faculty of the Wagner Free Institute of Science, Philadelphia, with a bibliography of his contributions to science. Arranged and edited by Joseph Leidy, Jr., M. D. Smithsonian Misc. Coll., part of vol. 46, 1904, 281 pages.

[b] A flora and fauna within living animals. Smithsonian Contr. Knowl., vol. 5, 1853, pp. 68, 10 plates.

I have studied one important class—the Rhizopods as they occur in all fresh waters of the country from the Atlantic border to an altitude of 10,000 feet in the Rocky Mountains. The marine forms of Rhizopods, in all times, have extensively contributed to the construction of stratified rocks. The determination of the living fresh-water forms may serve as a guide to the discovery and determination of fossil forms in the vast lacustrine formations in the interior of our continent." The volume is beautifully illustrated with forty-eight large plates in color from Leidy's exquisite drawings. The work illustrates the simplicity of Leidy's methods when he observes that all his observations were carried on with a small microscope costing only $50, and that the total expense to which he put the Geological Survey during his explorations in the West amounted to $222. The spell which the work cast about him is shown in his concluding remarks: "I may perhaps continue in the same field or research and give to the reader further results, but cannot promise to do so; for though the subject has proved to me an unceasing source of pleasure, I see before me so many wonderful things in other fields that a strong impulse disposes me to leap the hedges to examine them." This culminated Leidy's study of this group, begun in his student days, when he had observed for the first time the amœboid motions of the white blood corpuscles.

One of his most important observations in the field of microscopy was presented in a brief note of May 5, 1886, under the title, "Remarks on parasites and scorpions." [a] Leidy described three specimens of worms obtained from an anemic cat, presumed to be specimens of *Ankylostoma duodenale,* which was sent to him by Dr. Belfield, of Chicago, for determination. He remarked:

> On superficial examination I supposed the worms might belong to *Strongylus tubæformis,* a closely related parasite infesting the cat. The specimens, however, exhibit the same structure of the mouth as is described in the *Ankylostoma duodenale* of man. . . . [Description follows.]
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> The finding of this parasite in the cat in this country renders it

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[a] Remarks on parasites and scorpions. Trans. Col. Phys. Philadelphia, 3d ser., vol. 8, 1886, pp. 441–443.

probable that it may also infest man with us, and is probably one of the previously unrecognized causes of pernicious anemia.

This communication was made by Leidy to the College of Physicians of Philadelphia before the full significance was recognized of the presence of the hookworm in man as a cause of anemia—a subject subsequently developed through the investigations of Dr. C. Wardell Stiles as of the first importance in medecine.[a]

Leidy, in alluding to the work of Dr. John K. Mitchell on the fungus origin of malaria, denied this origin and treated Mitchell's work as speculative, in which position he was correct. It is doubtful whether he entertained the idea that malaria could not be or was not of parasitic origin, because the etiology was not then known, and it would have savored too much of dogmatism. He remarks: "The production of certain diseases, however, through the agency of entophyta, is no longer a subject of doubt, as in the case of Muscardine in the silk-worm, the Mycoderm of *Porrigo favosa* in man, etc.; but that malarial and epidemic fevers have their origin in cryptogamic vegetables and spores requires yet a single proof.[b] If such were the case, these minute vegetables and spores, conveyed through the air and introduced into the body in respiration, could be detected[c] (p. 14).

Leidy had a marked interest in the problem of "spontaneous generation"; his work covered a long period at intervals of patient research work; his conclusions were referred to in the text and in the footnotes appended to the introduction of "A flora and fauna within living animals" (1853). He made an extended reference to further investigations in his address before the medical students of the university in a lecture published in 1858 and 1859.

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[a] "The worms from the cat were not *A. duodenale* of man, but apparently *A. caninum,* which is very common in dogs." C. W. Stiles, letter to H. F. Osborn.

[b] See "an ingenious little work by my distinguished friend, Dr. J. K. Mitchell, 'On the cryptogamous origin of malarious and epidemic fevers."

[c] "A flora and fauna within living animals." Accepted for publication December, 1851. Smithsonian Contr. Knowl., vol. 5, Art. 2, April, 1853, pp. 67, 10 plates.

Prof. Henry B. Ward[a] gives the following estimate of the value of Leidy's work on the lower organisms:

> His contributions to comparative anatomy among invertebrate groups are no less important; both among insects and mollusks he contributed investigations which form the basis of our present knowledge of these groups. It was, however, among the lower forms that his work was particularly noteworthy. Here he entered upon fields comparatively unbroken and achieved results of the highest permanent value. His work on Protozoa is well shown in a magnificent monograph[b] whose artistic and accurate figures were all the work of his own pencil. All his observations were made with wonderful precision in view of the simple instrument at his command. Thus, for instance, he noted in 1849 and in 1851[c] that the Gregarinida are provided with muscle fibers, a view which was denied by European observers until thirty years later it was confirmed by the younger Van Beneden.
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> In some respects his most striking work was done in the field of helminthology. Among his very first papers was one in 1846 on an entozoan from the pig, in which he announced that he had discovered a minute encysted worm, which he regarded at *Trichina spiralis,* heretofore considered as peculiar to the human species. This observation attracted the attention of Leuckart, who in his monograph gives due credit to Leidy, and suggested that trichinosis in man might be due to the eating of raw pork containing the parasite (pp. 273–274).
>
> A series of helminthological contributions ran from 1850 to 1856, culminating in his Synopsis,[d] which is the only paper of its kind that has yet appeared in this country (p. 274).

Prof. Gary N. Calkins writes:

> There is really not much that I can add to what he [Ward] has given except a word of appreciation for his splendid work as a pioneer on American Protozoa. His monograph on the rhizopods is a splendid production and will stand as a classic. It well illustrates his powers of careful observation, keen insight into the structures, and their bearings on the vital activities of these forms. Not only rhizopods, but many other types of Protozoa as well, are carefully noted and affinities made out. On the whole, Leidy's work is to be classed as taxonomic rather than biologic. His particular genius here seemed to be morpho-

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[a] Ward, Henry B.: Notices Biographiques, VIII. Joseph Leidy, M. D., LL. D. Archives de Parasitologie, tome 3, 1900, pp. 269–279.

[b] Fresh-water rhizopods of North America. Rept. U. S. Geol. Survey Territories, vol. 12, 1879, pp. xii and 324, 48 pls.

[c] Proc. Acad. Nat. Sci. Philadelphia, vol. 4, pp. 226–233; and vol. 5, pp. 205–210.

[d] A synopsis of Entozoa and some of the ectocongeners. Proc. Acad. Nat. Sci. Philadelphia, vol. 8, 1856, pp. 42–50.

logical, his quick eye noting any differences which might indicate novel types. It may be stated that Leidy was undoubtedly the foremost student of Protozoa in this country at his time—a fact which illustrates his wonderful breadth of view and keen interest in all things pertaining to natural history.[a]

To his helminthological work numerous references have already been made. He brought together a vast amount of material and the studies made on this were communicated to the world mostly in the form of brief articles rather than finished contributions. Nevertheless, his keen insight into comparative anatomy led him to outline many natural genera, such as *Clinostomum,* to which the newer generation of students are just returning as natural subdivisions. While these observations were made with great keenness of perception, it must still be confessed that they were often expressed in quite too brief form for clear general understanding. In this he only followed the plan of his European contemporaries, and while his ideas are distinct with the specimen itself in view, it is undoubtedly true, as in the case of many other great workers of the past generation, that the original specimens must be worked over more fully to establish their actual taxonomic position. It is sad to record that his helminthological work was left unfinished. In the five volumes of *Leidyana* presented to the Philadelphia Academy by Dr. Nolan are included four volumes of drawings and notes which are a veritable mine of helminthological information. An unfinished monograph of the Gregarines is indicated by the 176 unpublished illustrations of these forms from twenty-one hosts which occur among these drawings; and the wide range of other helminthological work shows well that his project of a monograph on parasites would have given the world a work the loss of which we may well mourn. But though unfinished, his contributions will form the basis of American work in the future as they have furnished in some directions even to the world the foundation for past work in this department. Leidy's reputation as a helminthologist was certainly cosmopolitan, as is clearly evinced by the numerous references to his contributions in the works of Cobbold, Diesing, and of that master of helminthology, Rudolph Leuckart (pp. 276–277).

Dr. C. W. Stiles gives the following estimate of Leidy's work:[b]

Our estimate of Leidy's work on parasites must vary with our point of view. If we belong to the class of students who try to judge the work of a broad general zoölogist of 1880–1890 from the point of view of a specialist of 1910, we must conclude that Leidy's results were inferior. If we belong to the class of students who recall that all efforts should be judged in connection with their period, we must conclude that Leidy was not only the American pioneer, but a brilliant pioneer in this field of zoölogy.

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[a] Letter to Professor Osborn, April 30, 1912.

[b] Letter to Professor Osborn, May 18, 1912.

From a viewpoint of public health, his discovery of *Trichinella spiralis* in swine seems to be his most important practical contribution to helminthology. In addition, his systematic work had considerable value which for years was overlooked.

His other great public-health contribution seems to me to be his observation on flies as apparent spreaders of disease. It concerned flies in hospital wards during the war, 1861–1865, as spreaders of infection to wounds.

Leidy, in 1879, reached a stage in the classification of parasitic amœbæ which the rest of the world did not reach until years later. He recognized that parasitic amœbæ, like the amœbæ of the water-roach, should be separated from the free living forms, but I do not recall any modern author on amœbiasis who has seen this historical point.

Insects and protozoa as possible disease-carriers were constantly in Leidy's mind. Dr. Frank E. Lutz contributes[a] the following interesting notes gathered from twenty-three of Leidy's contributions on insects:

In most of Leidy's best work insects play the incidental rôle of hosts of the micro-animals and plants he was really investigating. He apparently was much interested in them as objects for observation, as is shown by the numerous short notes he presented before the Academy of Natural Sciences, but he wrote no important paper on a purely entomological subject. In 1846 he published two short but interesting notes on the anatomy of certain Orthoptera, and in 1852 made the suggestion that the disappearance of tracheæ from the repletes of the honey-ant prevented the digestion of the "stored" honey. In the same year he worked with Langstroth on the question of the fertilization of the eggs of the honey-bee, advocating the now accepted idea that spermatozoa are stored for some time in the spermatheca of the queen. In 1853 he discussed the cause of malaria and wrongly concluded that it is not of parasitic origin; but in 1871 he suspected the carrying of smallpox and gangrene by flies, proving that they do carry spores of the fungus *Peallus impudicus*.

CONTRIBUTIONS TO PALÆONTOLOGY.

Sir Charles Lyell's "Principles of Geology," published in 1839, appears to have exerted a direct influence upon Leidy, as upon Darwin and many others, in arousing his interest in geology. After Lyell had visited young Leidy in his home in Philadelphia he wrote to him in 1883: "Give serious attention and devote your time to palæontology." It is a piece of interesting history that in Leidy's address many years afterward to Sir William Flower, acknowledging the award of the Lyell Medal by the council of the Geological Society of London, he says: "I must add that I feel as if Sir Charles himself was expressing satisfaction in consideration of my having complied with his wish, when thirty years ago in my own home here he said he hoped I would devote my time to palæontology instead of to medicine."

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[a] Letter to Professor Osborn, April 29, 1912.

Leidy's observations in palæontology were first directed to specimens found in a cave in Mississippi near Natchez, supposed to include fossil human bones, in 1845, and presented at a meeting of the Academy of Natural Sciences. The untrodden field of palæontology opened before him as his greatest opportunity. A number of stray memoirs, notable among them those of Vice-President Thomas Jefferson and Dr. Harlan, upon the extinct sloth of America, the *Megalonyx jeffersoni*, had already been published, but no systematic work or connected statement covering the remarkable extinct fauna of the eastern coast of our continent had as yet been attempted. From the scanty materials in the academy and from scattered specimens sent to him by amateur collectors, Leidy, in the year 1847, at the age of twenty-four, published his first important paper on the fossil horse of America, in which he proved beyond a doubt that the horse, though extinct at the time of the discovery of America, had existed on this continent in prehistoric times. This had been preceded by several palæontological notes—*e. g.*, November 18, 1845. We find him inquiring into the causes which may have brought about the extinction of the horses on our continent, and his inquiry was formulated as follows: "At present their existence is being fully confirmed; it is probably as much a wonder to naturalists as was the first sight of the horses of the Spaniards to the aboriginal inhabitants of the country, for it is very remarkable that the genus *Equus* should have so entirely passed away from the vast pastures of the western world, in future ages to be replaced by a foreign species to which the country has proved so well adapted. It is impossible in the present state of our knowledge to conceive what could have been the circumstances which have been so universally destructive to the genus on one continent and so partial in its influence upon another." Twelve years later we find much the same proposition stated in the following words in Darwin's "Origin of Species": "For seeing that the horse since its introduction into South America has run wild over the whole country and has increased in numbers at an unparalleled rate, I asked myself what could so recently have exterminated the former horse under conditions of life apparently so favorable." [a]

Leidy's wide and accurate knowledge of human and comparative anatomy, together with his extraordinary power of detecting resemblances, enabled him to make remarkable deductions from even the fragmentary materials which were submitted to him. In the year 1847 he described the first cameloid (*Poëbrotherium*) from the Oligocene of the Western Territories.

In 1848 there are two notices of western forms, and from this time on until 1870 all the great materials from the West came into Leidy's hands, affording him the unparalleled opportunity of laying the foundations of American palæontology. As early as 1846 there had appeared in the American Journal of Arts and Sciences the description by Hiram A. Prout of part of a jaw which the author referred to "*Palæotherium,*" from the *Mauvaises Terres,* near the White River, Nebraska. This jaw subsequently was referred to Leidy and he distinguished it as *Titanotherium.* It has become the type of the titanotheres, one of the most important families of mammals which Leidy discovered. These early papers on the mammals of Nebraska proved to be of the greatest importance, because they served to draw the attention of scientists to the exploration of the rich fossil beds of the West. The history of early exploration is given in Leidy's memoir of 1869. The first bones were collected by amateur collectors and sent to the Academy of Natural Sciences. The first systematic scientific collections were made by Dr. John Evans (1849) and by Thaddeus Culbertson (1850); the latter, at the instigation of Spencer F. Baird, immediately sent the fossils to Leidy for study and description, remarking that he was the only anatomist qualified to make the determination. Leidy's observations on this collection were presented in a series of notices in the Proceedings of the Academy. Leidy described and figured the forms mentioned in his "Description of the Remains of Extinct Mammalia and Chelonia from Nebraska Territory," published in 1852, and his final report was in "The Ancient Fauna of Nebraska, a Description of Extinct Mammalia and Chelonia from the Mauvaises Terres of Nebraska," published in 1854. In this the oreodonts, rhinoceroses, elotheres, and horses, as well as the titanotheres (*Palæotherium*) and Testudinata, chiefly of the Lower Oligocene, but referred to the Eocene, were first described. It was in the same year, 1852, that Leidy had arranged to accompany an expedition to the West to collect fossils; he particularly desired to go in order to make his own observations on the occurrence of the fossil remains, and it must always be deplored as a great loss to science that he was unable to carry out these plans. His mind was now concentrated upon vertebrate palæontology. One by one he thoroughly established the distinction of the New World from the Old World forms, first in the Oligocene, then, as the field of exploration broadened, in the Miocene and Pliocene areas. In the meantime the mammals of the eastern Pleistocene were successively treated in short but clear descriptions, always accompanied by close comparisons with the living and extinct forms of the Old World. "The Ancient Fauna of Nebraska," accepted for publication by the Smithsonian Institution in 1852, appeared in 1854. This was his last synthetic contribution to the western mammals prior to the publication of his great memoir of 1869. In the meantime Leidy's work, "A Memoir on the Extinct Sloth Tribe of North America," was prepared in 1853 and published in 1855. This was a companion to his other important works, "A Memoir on the Extinct Dicotylinæ of North America," presented to the Philosophical Society in 1852 and published in 1853 also to his memoir "On the Extinct Species of American Ox," completed in 1852 and published in 1853 by the Smithsonian Institution.

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[a] See Angelo Heilprin's manuscript memoir, "Dr. Leidy's work in geology and palæontology."

Dr. F. V. Hayden's explorations in the Judith and Musselshell rivers of Missouri in 1855 yielded to Leidy the first knowledge of the Upper Cretaceous reptilian fauna, including the Crocodilia, the Iguanodontia, and carnivorous dinosaurs. The first comprehensive account of these animals was Leidy's memoir, "Extinct Vertebrata from the Judith River and Great Lignite Formations of Nebraska," published by the American Philosophical Society in 1860. It will be observed that at this time the whole western territory was comprised within Nebraska. Leidy's comprehensive review of eastern and western mammals was completely paralleled by his equally comprehensive examination of the eastern and western reptiles. In 1857 he began his monographic revision of the Cretaceous reptiles of the United States, which comprehended those of New Jersey, Maryland, Delaware, North Carolina, Georgia, Alabama, Mississippi, and Nebraska. The last embraces not only the Judith River forms, first described, but from other parts of the West, adding the mosasaurs, plesiosaurs, and many new types of Crocodilia and Testudinata to his previous description. The mosasaurs carried his work into the Middle Cretaceous. It is interesting to note that the commission to which this memoir was referred by the Smithsonian Institution included Louis Agassiz and Edward D. Cope, the latter destined to soon succeed Leidy in both the reptilian and mammalian field. While extremely valuable for its exact description, this memoir on the "Cretaceous Reptiles of the United States," published in 1865, was rather a synthesis of all existing knowledge and an exact description and determination of a very fragmentary series of types than an attempt at classification or determination of the relationships and habits of the animals described; in fact, the material was far too fragmentary to admit of philosophic work. Even in the hands of Owen the classification of the extinct Reptilia was in a rudimentary stage. Nevertheless, this memoir, taken with that on the reptiles of the Judith River, constitutes the foundation of the reptilian palæontology of America. Brief reference should also be made to Leidy's work on the eastern saurians, such as *Bathygnathus* ? (1853) and "Descriptions of some remains of fishes from the Carboniferous and Devonian formations of the United States," published in 1856 by the Academy of Natural Sciences.

It is important to note that in all these treatises, although not having visited the territory described, Leidy made a serious effort in conjunction with the geological work of Dr. F. V. Hayden to determine the geological levels of the forms described.

Leidy's grandest contribution to palæontology is his memoir of 1869, entitled "The Extinct Mammalian Fauna of Dakota and Nebraska." This not only covers all his own researches on the western forms, but embraces a complete synopsis on the mammalian palæontology of North America up to the year of publication, which is absolutely invaluable to the student of the history of the subject. This synopsis of early palæontology in this country is a priceless repertoire of the first period of mammalian palæontology in America, what may be called the pre-Darwinian Period. The illustrations in thirty lithographic plates, executed under Dr. Leidy's direction, are masterpieces of accuracy and have served for all subsequent determinations. The materials for the work had been accumulating for twenty-three years; those of the synopsis of the mammalian remains of North America had been accumulating for a century and a half. The preparation of the work occupied Leidy, with various interruptions, for a period of seven years. In the preface we once more observe Leidy's regard for fact rather than theory:

> The present work is intended as a record of facts, in palæontology, as the authors have been able to view them—a contribution to the great inventory of nature. No attempt has been made at generalizations or theories which might attract the momentary attention and admiration of the scientific community. We give this premonition at the outset, to prevent disappointment in those who might be expectant of more important results than we have obtained from the great amount of material at our command. We have endeavored to see and represent things correctly, nothing more, though we apprehend we have not been able to avoid the average amount of errors usual under such circumstances.

The geological introduction by Dr. F. V. Hayden illustrates the extremely rudimentary knowledge of geological succession which prevailed at that time, the Tertiary rocks being divided into four groups as follows:

Loup River beds, 300–400 feet	Pliocene
White River group, 1,000 or more feet	Miocene
Wind River deposits, 1,500–2,000 feet	(?)
Fort Union or Great Lignite group, 2,000 feet	(?)

Leidy himself, however, made a remarkably accurate presentation of the vertical range of species (p. 20). His subdivisions, A, B, C, D, E, and F, have been used largely by Matthew (1899).[a] Matthew's identification of the Hayden and Leidy stratification is as follows:

F = Loup Fork = Upper Miocene
E = Ticholeptus Zone = Middle Miocene
D = Lower Miocene
C = Leptauchenia Zone or Protoceras Zone = Upper Oligocene
B = Oreodon Zone = Middle Oligocene
A = Titanotherium Zone = Lower Oligocene

At the time, the deposits in Nebraska and Dakota were all considered of lacustrine origin, and Leidy shows his sagacity in pointing out the absence of the remains of birds and fishes, and the fact that the single reptile known is a land turtle. It is now believed that these deposits are flood-plain—an interpretation which accounts for the absence of aquatic forms. Leidy returns to this subject in his concluding remarks:

> . . . In this view of the formations we are led to inquire why they exhibit no traces of fishes or aquatic mollusca mingled with the multitude of relics of terrestrial mammals. Even remains of the latter of decided aquatic habit are absent. With the exception of the marsh-loving rhinoceros and the beaver, no amphibious mammals have been discovered; not even the hippopotamus, whose remains are frequent in contemporaneous formations of Europe and Asia.
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> The constitution of the skeletons of most fresh-water fishes, though comparatively unfavorable to their preservation as fossils, can hardly be admitted as a sufficient reason for the total absence of their remains

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[a] A Provisional Classification of the Fresh-water Tertiary of the West. Bull. American Mus. Nat. Hist., vol. 12, Art. 3, March 31, 1899, pp. 19–75.

> in the formations in question. The conditions during which the formations of the Mauvaises Terres were deposited would appear to have been especially favorable for the preservation of the most delicate structures. The mammalian fossils, in the perfect preservation of their original sharpness of outline without the slightest trace of erosion and the character of their containing matrix, indicate quiet water with a soft muddy bottom. The chemical constitution, too, of the matrix and fossils indicate a petrifying quality in the mud and water favorable to the preservation of any animal skeleton.
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> The absence of remains of fishes and aquatic mollusks in association with the mammalian fossils, both in the Niobrara and Nebraska formations, may be accounted for by supposing that the lakes in which were formed the deposits containing the fossils may have been periodically subjected to admissions of salt water from the ocean, thus inducing a condition unfavorable to life in the lake waters.

He comments on the absence of crocodiles. He also introduces a few generalizations. It is noted that in the form of the skull the Oligocene forms present a greater uniformity of structure than the existing mammals. A valuable classification based on the system of Richard Owen is presented. A dissimilarity of the Oligocene and closer similarity of the Pliocene mammals to those of the Old World is noted. The presence of sloths is attributed to South American migration. Community of fauna with Europe is explained by a continental connection with Asia. The extinction of a very large part of the Oligocene fauna is commented upon.

The next great volume of Leidy was his "Contributions to the Extinct Vertebrate Fauna of the Western Territories," begun in 1870 and completed in 1873.[a] As early as 1868, Dr. J. van A. Carter, of Fort Bridger, Wyoming, in correspondence with Leidy, had informed him of the frequent occurrence of the remains of turtles and other animals in the buttes of the neighboring country. During the same year Hayden commenced his geological observations in these great Middle Eocene deposits, now known as the Bridger formation, which opened a new chapter in the history of the American fossil vertebrates. Leidy's first notice of these fossils appeared in the Proceedings of the Academy of Natural Sciences, April, 1869, in the mention of a little supposed Insectivore, *Omomys*

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[a] Contributions to the extinct vertebrate fauna of the Western Territories. Rept. U. S. Geol. Surv. Terr., vol. 1, 1873, 40, pp. 358, pls. 37.

carteri, which he named after Dr. Carter. The animal has since been determined as belonging to the Primates. Descriptions of many other forms appear in the Proceedings of the Academy of Natural Sciences of 1870–1873, followed by the publication of the memoir. When the volume was ready for the press, in the summer of 1872, Leidy received an invitation to visit Dr. Carter at Fort Bridger, which he accepted with delight, and thus on the eve of the publication of his last great work on palæontology he beheld for the first time one of the grand fossil-bearing regions of the West. Referring to an excursion into the Badlands, he writes:

> No scene ever impressed the writer more strongly than the view of one of these Badlands. . . . On ascending the butte to the east of our camp, I found before me another valley—a treeless barren plain, probably ten miles in width. From the far side of this valley, butte after butte arose and grouped themselves along the horizon, and looked together in the distance like the huge fortified city of a giant race. The utter desolation of the scene, the dried-up water-courses, the absence of any moving object, and the profound silence which prevailed, produced a feeling that was positively oppressive. When I then thought of the buttes beneath my feet, with their entombed remains of multitudes of animals forever extinct, and reflected upon the time when the country teemed with life, I truly felt that I was standing on the wreck of a former world (p. 18–19).

There follows a vivid description of the geology of the Basin which makes one regret that Leidy's first opportunity to visit the region had come so late in his life. The volume is mainly devoted (pp. 27–196) to the Eocene fauna, mammals, reptiles, and fishes, but there occurs also the first systematic account (pp. 210–226) of the mammals of the John Day River, Oregon. now known to be of Upper Oligocene age. The Miocene and Pliocene vertebrates determined by Leidy after the close of his memoir of 1869 are also treated (pp. 227–264). The volume concludes with Leidy's last contribution to the vertebrate fauna of the Cretaceous period (pp. 266–309) and a notice of Carboniferous fishes (pp. 311–313).

This important monograph therefore completes the foundations which Leidy laid down for the systematic determination of the extinct vertebrate life of America. Already, in 1872, Marsh and Cope had begun to collect in the Bridger Eocene field, and Leidy prophetically observes in his preface: "The investigations and descriptions by these gentlemen of some of the fossils from the same localities have been so nearly contemporary with mine that from want of the opportunity of comparison of specimens we have no doubt in some cases described the same things under different names and thus produced some confusion, which can only be corrected in the future." It has required nearly forty years of painstaking work to correct the confusion which Leidy refers to in this kindly note.

Marsh's contributions to western palæontology were begun in 1868.[a] Marsh had begun publishing in 1861. Cope began publishing in 1859, and it is noteworthy that his first paper on western vertebrates also appeared in 1868. While no doubt Leidy watched with keen satisfaction the promise of the development of the science in the hands of these younger men, an element of pathos entered into his own position. For the long period of twenty-one years (1847–1868) he had enjoyed a monopoly of vertebrate palæontology in America. Now the situation is suddenly changed; two younger men, full of energy and enthusiasm and with ample means, render it impossible for him to compete in the collection of fossils or to continue his best loved work. Sir Archibald Geikie, who visited Philadelphia in 1879, quotes Leidy's own words in explanation of his abandoning palæontology at this time: "Formerly," he said, "every fossil one found in the States came to me, for nobody else cared to study such things; but now Professors Marsh and Cope, with long purses, offer money for what used to come to me for nothing, and in that respect I cannot compete with them. So now, as I get nothing, I have gone back to my microscope and my Rhizopods and make myself busy and happy with them." Leidy's bibliography attests the truth of this statement. In 1874 there appear seventeen papers on Rhizopods and other microscopic forms and only four on fossil vertebrates. His active work between 1874 and 1879 culminated in his memoir, "Fresh-water Rhizopods of North America," of 1879. In the meantime, however, he began to renew his notices of vertebrate remains of the Eastern States, especially from the phosphate beds of South Carolina, which he collected in his two memoirs of 1874 and 1879.[a] In 1880 he describes the fauna of the bone cave in Pennsylvania and gives a second paper on *Bathygnathus*. Occasional contributions follow in succeeding years on the horses and peccaries, and in 1884 there begin his notices of the vertebrate fossils from Florida, which continued until 1889, when Leidy's last important contributions to vertebrate palæontology were published in the Transactions of the Wagner Free Institute of Science.[b] By an interesting coincidence these animals, which were partly obtained by Leidy's intimate friend, Mr. Joseph Willcox, were closely related to those from the Loup Fork of Nebraska, which Leidy had begun to describe in 1856, forty years before.

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[a] Notice of a new and diminutive species of fossil horse (*Equus parvulus*) from the Tertiary of Nebraska. American Journ. Sci., vol. 46, 1868, pp. 374–375.

EVOLUTION.

From the time of his first paper of 1847 on the fossil horse of America until his last paper of 1889, "On Hippotherium and Rhinoceros from Florida," Leidy was constantly accumulating facts for Darwin. It was a common saying that it is "a simple matter to construct the building after the materials are supplied." As a close observer of affinities of structure he anticipated by many years both Cope and Marsh in building up the materials for the phylogeny of the horses, camels, rhinoceroses, and other groups of ungulates. There does not seem to be a single case in which Leidy failed to recognize affinity. He showed extraordinary acuteness in distinguishing the various genera of Miocene and Pliocene horses; many of his determinations which were formerly questioned are now thoroughly established, yet with our understanding of Leidy's nature it is not surprising that he failed to place these animals in phyletic or successive stages and virtually left this phyletic reconstruction entirely to Cope and to Marsh. We may explain this partly by Leidy's indisposition to indulge in controversy, because he well knew that evolution was a keenly controverted question, partly by his unwillingness to indulge in theories which he did not consider thoroughly tested by facts; but chiefly it is attributable to his thoroughly Teutonic disposition to confine himself absolutely to direct observation and to amassing as large a number of well-attested facts as possible. He spent his life in amassing facts. He was often approached by this or that firm or representative of some book concern or journal to give expression to some new theory. His invariable reply was: "I am too busy to theorize or to make money. The time will come when such investigations as I may add from time to time may prove of value, and I believe I can do more good to science in adding some new facts than in preparing articles for popular treatises." The correspondence of Leidy with Hayden confirms this view. There is little doubt that during this entire formative period Leidy was practically an evolutionist, although the theory was not clearly formulated in his mind. He could hardly have been less, in view of his familiarity with the second volume of Lyell's "Principles of Geology." In this connection it is interesting to observe what Leidy, in prophetic vein, wrote in his memoir, "A Flora and Fauna within Living Animals," published in 1853, eight years before the publication of "The Origin of Species":

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[a] Description of vertebrate remains chiefly from the phosphate beds of South Carolina. Journ. Acad. Nat. Sci. Philadelphia, vol. 8, 1877, pp. 209–261.

Notice of a new and diminutive species of fossil horse (*Equus parvulus*), from the Tertiary of Nebraska. American Journ. Sci., 2d ser., vol. 46, 1868, pp. 374–375.

[b] Description of mammalian remains from a rock crevice in Florida. Trans. Wagner Free Inst. Sci. Philadelphia, vol. 2, 1889, p. 15.

Description of vertebrate remains from Peace Creek, Florida. Idem, pp. 19–31.

Description of some mammalian remains from the salt mine of Petite Anse, Louisiana. Idem, pp. 33–40.

> The study of the earth's crust teaches us that very many species of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result in many cases of a change in exterior conditions incompatible with the life of certain species and favorable to the primitive production of others. Living beings did not live upon earth prior to their indispensable conditions of action, but wherever these have been brought into operation concomitantly, the former originated. Of the life present everywhere, with its indispensable conditions and coeval in its origin with them, what was the immediate cause? It could not have existed

upon earth prior to its essential conditions, and is it therefore the result of these? There appear to be but trifling steps from the oscillating particle of organic matter to a Bacterium; from this to a Vibrio; thence to a Monad, and so gradually up to the highest orders of life. The most ancient rocks containing remains of living beings indicate the contemporaneous existence of the more complex as well as the simplest of organic forms; but, nevertheless, life may have been ushered upon earth through oceans of the lowest types long previously to the deposit of the oldest Palæozoic rocks as known to us.

With Asa Gray, he was among the very first to accept Darwin's theory of the origin of species; for immediately after the appearance of the first edition of Darwin's work, in 1859, upon the recommendation of Leidy and of Dr. Isaac Lea, Darwin was elected a member of the Academy of Natural Sciences of Philadelphia, March 27, 1860. Thus the Academy was one of the first institutions to honor Darwin after the publication of his great work. Of this support Darwin wrote to Sir Charles Lyell:

> MY DEAR LYELL: This morning I got a letter from the Academy of Natural Sciences Philadelphia announcing that I am elected a correspondent member. It shows that some naturalists do not think me such a scientific profligate as many think me here.
>
> Yours gratefully, CHAS. DARWIN.

In March, 1860, Darwin himself wrote a letter to Leidy referring to his early accounts of the horse and camel tribes.

HONORS.

In the year 1869 the honorary degree of LL. D. was conferred on Leidy by the Franklin and Marshall College of Lancaster. Not long after this he received his appointment as professor of natural history in Swarthmore College, and for fourteen years he lectured once or twice weekly to the students. His reputation kept steadily growing on both sides of the Atlantic and each fresh volume brought him new fame. In palæontology he was held as the Cuvier of America, while as an anatomist and zoölogist he was held in high esteem. In 1863 Leidy became one of the fifty leading men of science of America who joined in the incorporation of the National Academy of Sciences (March 3, 1863). When he went abroad in

1875 for the third time his acquaintance was sought by scientists everywhere. In 1879 he was elected an honorary member of the Royal Microscopical Society of London; of the Zoölogical Society of London in 1883. In the year 1880 the Boston Society of Natural History awarded to him the Walker Grand Prize for 1879 for prolonged investigations and discoveries in zoölogy and palæontology, and in consideration of the extraordinary merit of Leidy's works the sum awarded was $1,000. In 1884 the Geological Society of London awarded to Leidy its Lyell Medal in recognition of his researches in geology and palæontology. In announcing the award of the medal, Sir Archibald Geikie said: "Among the scientific laborers in the palæontological harvest field, Dr. J. Leidy has held a foremost place. Careful in observing, accurate in recording, cautious in inferring, his work has the high merits which trustworthiness always imparts." This award was followed not many years afterward by that of the Cuvier Prize Medal, sent to Leidy by the Institute of France. In 1886 Harvard University conferred on Leidy the honorary degree of LL.D.

BIOGRAPHIES AND BIBLIOGRAPHIES OF JOSEPH LEIDY.

The present writer is chiefly indebted to Dr. Joseph Leidy, Jr., a nephew of Leidy, for many of the personal references in the above review, as well as for calling attention to the dates of some of Leidy's most important discoveries. The bibliography prepared by Dr. Leidy for his important review of the elder Leidy's work, entitled "Researches in Helminthology and Parasitology, by Joseph Leidy, M. D., LL. D.," is the most complete which has been published, and is reprinted herewith, with corrections and the addition of a few omitted titles.

The writer is indebted also to Dr. Joseph Willcox, of Philadelphia, an intimate friend of Leidy's, for an opportunity to examine the journal taken on Leidy's last journey abroad and for some interesting personal experiences.

On the whole, the memoir of Joseph Leidy prepared by the late Dr. Henry C. Chapman for the Academy of Natural Sciences is the most authentic of the ten which have been prepared and published by various writers. It appears that W.

Ruschenberger's sketch for the American Philosophical Society contains some matter which is less authentic. The most appreciative reviews of Leidy's contributions to geology and palæontology are those of Persifor Frazer (1892), of Angelo Heilprin (unpublished address), and of Archibald Geikie (1892). Relating especially to Leidy's contributions to helminthology is the brief memoir by Henry B. Ward, prepared for the French Archives de Parasitologie (1900). The memoir by Dr. William Hunt was published for private distribution. There is also a biographical note in Spitzka's "Study on Brains," published by the American Philosophical Society. The fullest information regarding the life of Leidy will, however, be found in the biography now in course of preparation by Dr. Joseph Leidy, Jr.

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[On the existence of an Entozoön (*Trichina spiralis*) in the superficial part of the extensor muscles of the thigh of a hog.] Idem, pp. 107–108.

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[Observations on the structure of the intervertebral substance of man.] Idem, p. 243.

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[On *Bison latifrons, Arctodus pristinus, Hippodon speciosus,* and *Merycodus necatus.*] Idem, pp. 89–90.

[On *Dinictis felina.*] Idem, p. 127 (6 lines).

[Reply to Professor Lindley's criticisms of a "Flora and Fauna within Living Animals."] Idem, pp. 128–129.

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Description of a fossil apparently indicating an extinct species of the Camel tribe, *Camelops kansanus.* Idem, pp. 172–173.

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Notice of some Fossil Bones discovered by Mr. Francis A. Lincke in the banks of the Ohio River, Indiana (describes a new species of wolf, *Canis primævus*). Idem, pp. 199–201.

[On *Hydrachna.*] Idem, p. 202 (4 lines).

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[Perforation of oyster and clam shells by a sponge of the genus *Cliona*.] Idem, pp. 162–163.

Notice of some remains of vertebrated animals. Idem, pp. 163–165.

Notices of remains of extinct vertebrated animals of New Jersey, collected by Professor Cook, of the State Geological Survey, under the direction of Dr. W. Kitchell. Idem, pp. 220–221.

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Remarks on certain extinct species of fishes. Idem, pp. 301–302.

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[On the new red sandstone fossils from Gwynedd, Pa.] Idem, p. 150 (5 lines).

Notices of some remains of extinct fishes. Idem, p. 167.

Rectification of the references of certain of the extinct Mammalian genera of Nebraska. Idem, pp. 175–176.

[On the dentition of *Mososaurus;* also on *Oecanthus.*] Idem, pp. 176–177.

[On a large species of *Gordius* and a larva of *Oestrus.*] Idem, p. 204.

[On a curious animalcule found on the stones and dead plants in the Schuylkill and Delaware rivers, *Dictyophora vorax*.] Idem, p. 204 (18 lines).

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Remarks on Saurocephalus and its allies. Idem, pp. 91–95, pl. vi (part).

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Remarks on the structure of the feet of *Megalonyx*. Idem, vol. 11, pp. 107–108.

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[On voluntary moving bodies in the stomachs of *Urnatella gracilis*.] Proc. Acad. Nat. Sci. Philadelphia, vol. 10, p. 1 (10 lines).

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[On fossil remains from the Niobrara River.] Idem, p. 7.

[On Pliocene fossils from Nebraska.] Idem, p. 7 (12 lines).

[A new species of mastodon and elephant from Nebraska, *Mastodon mirificus, Elephas imperator*.] Idem, p. 10 (16 lines).

[On the fossil remains of the horse found in the post-Pliocene deposits of the United States.] Idem, p. 11.

[Fossil mastodon.] Idem, p. 12.

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[On *Manayunkia speciosa*.] Idem, p. 99 (15 lines).

Contributions to Helminthology. Idem, pp. 110–112.

[Two species of *Ichneumon*, infesting the chrysalides of the canker-worm.] Idem, p. 137 (6 lines).

[On *Rhynchodemus sylvaticus*.] Idem, pp. 171–172.

[A species of *Cristatella, Fredericella,* and *Lophopus*.] Idem, pp. 188–190.

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[Remarks on consciousness and automatism.] Idem, pp. 6–7.
[Remarks on an Acephalous fœtus.] Idem, pp. 8–9.
[Remarks on blood crystals.] Idem, p. 9 (5 lines).
[Remarks on honey dew.] Idem, p. 10 (10 lines).
[Remarks on death from chloroform.] Idem, p. 11 (5 lines).
[Remarks on sections of the human cranium.] Idem, p. 10 (8 lines).
[Remarks on *Echinococcus hominis*.] Idem, p. 12 (9 lines).
[Remarks on disease of the scales of minnows.] Idem, pp. 12–13.
[Remarks on growth of hairs on the cornea of an ox.] Idem, p. 15 (4 lines),
[Remarks on mucous corpuscles.] Idem, p. 16 (6 lines).
[Remarks on the stomach of a mink (*Mustela vison*) containing a large number of worms.] Idem, p. 25 (18 lines).
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[On fossil fishes, *Xystracanthus arcuatus* and *Cladodus occidentalis*.] Idem, p. 3.
[On a Mastodon tooth from Honduras, teeth and fragments of teeth of Mosasaurus from the green sand of New Jersey.] Idem, p. 91.
[Remains of fishes found in Triassic shales at Phœnixville, new species, *Eurydorus serridens*.] Idem, p. 110.
[On fossil bones contained in so-called guano from Sombrero, W. I., and on *Ursus americanus* and Mastodon from Mississippi.] Idem, p. 111.
[On *Palæotrochus*.] Idem, p. 150 (5 lines).
On *Dromatherium sylvestre* and *Ontocetus emmonsii*. Idem, p. 162.
[On the fossil horse.] Idem, pp. 180–185.
[On an animalcule, *Freyia americana*.] Idem, p. 194 (15 lines).
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[On *Trichina in the human muscle*.] Idem, p. 3 (3 lines).
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[On *Hyalomena from Japan*.] Idem, p. 85 (15 lines).

[On *Trichina spiralis*.] Idem, p. 96 (13 lines).

[Remarks on a rich botanical locality near Philadelphia.] Idem, p. 98 (10 lines).

[On a specimen of *Hyla*.] Idem, p. 305 (3 lines).

[On fossil horse teeth from Washington Co., Texas.] Idem, p. 416 (7 lines).

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On specimens of *Nostoc pruneiforme.* Idem, p. 281 (2 lines).

1865.

[On the existence of a boring sponge during the Cretaceous period.] Proc. Acad. Nat. Sci. Philadelphia, vol. 17, p. 77 (5 lines).

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[On a Kjökkenmödding.] Idem, p. 95.

[On a fœtal dog shark, *Acanthias americanus.*] Idem, p. 175 (10 lines).

[On fossil rhinoceroses. Description of *Rhinoceros meridianus* and *Rhinoceros hesperius.*] Idem, pp. 176–177.

[On specimens of oolitic phosphates of lime and alumina.] Idem, p. 181 (8 lines).

[On cryolite.] Idem, p. 181 (4 lines).

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[On a foot bone of *Hadrosaurus* from Columbus, Miss.] Idem, p. 9.

[Cancer of the liver found in a turkey, with remarks upon *Trichina* and other Parasites.] Idem, p. 9.

[Remarks upon fossil bones of the elephant, etc., found in a salt mine on the Island of Petite Anse, Louisiana.] Idem, p. 109.

[Observations upon a small collection of fossils from Bangor, Maine.] Idem, p. 237.

[Exhibition of teeth of *Mastodon ohioticus* from Big Bone Lick, Ky.] Idem, p. 290 (5 lines).

[On *Drepanodon* or *Machairodus occidentalis.*] Idem, p. 345 (6 lines).

1867.

[On fossil Hippopotamus.] Proc. Acad. Nat. Sci. Philadelphia, vol. 19, p. 32 (4 lines).

[On *Bison latifrons* and the skull of *Bison antiquus.*] Idem, p. 85.

[On the seventeen-year Locust.] Idem, p. 93 (2 lines).

[On a fossil skull of *Geomys bursarius.*] Idem, p. 97 (6 lines).

[On a fossil skull of *Castoroides ohioenis.*] Idem, pp. 97–98.
[Remarks on antique copper implements.] Idem, p. 97 (9 lines).
[Reference to specimens of black hornstone.] Idem, p. 125 (4 lines).

1868.

[On *Sombrero guano.*] Proc. Acad. Nat. Sci. Philadelphia, vol. 20, p. 156 (5 lines).
Notice of some Vertebrate remains from Harden Co., Texas. Idem, pp. 174–176.
Indications of an *Elotherium* in California. Idem, p. 177.
Notice of some reptilian remains from Nevada. Idem, pp. 177–178.
Notice of some Vertebrate remains from the West Indian Islands. Idem, pp. 178–180.
Notice of some remains of Horses. Idem, p. 195.
Notice of some extinct Cetaceans. Idem, pp. 196–197.
Remarks on jaw of *Megalosaurus.* Idem, pp. 197–200.
Remarks on *Conosaurus* of Gibbes. Idem, pp. 200–202.
Notice of American species of *Ptychodus.* Idem, pp. 205–208.
Synopsis of Mammalian remains of North America. Idem, p. 202. (Announcement.)
[On the stomach of shad containing small fish.] Idem, p. 228 (9 lines).
Notice of some American Leeches. Idem, pp. 229–230.
Notice of some remains of extinct *Pachyderms.* Idem, pp. 230–233.
On Coprolites from the Huronian slates. Idem, p. 302.
On the cause of iridescence in opals. Idem, p. 303.
On asterism in mica. Idem, p. 313.
On remains of extinct *Insectivora.* Idem, p. 315.
On *Wolffia columbiana,* the smallest and simplest of all flowering plants. Biological and Microscopial section, Acad. Nat. Sci. Philadelphia, pp. 6–7.
[A new species of sponge, *Pheronema annæ.*] Idem, pp. 9–10.
On *Euglena.* Idem, p. 11.

1869.

Notice of some extinct vertebrates from Wyoming and Dakota. [1. *Omomys carteri.* 2. *Nanohyus porcinus.* 3. *Trionyx guttatus.* 4. *Emys wyomingensis.* 5. *Crocodilus aptus.*] Proc. Acad. Nat. Sci. Philadelphia, vol. 21, pp. 63–67.
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On the *Elasmosaurus platyurus of Cope.* American Journ. Sci., 2d ser., vol. 49, p. 392.

[Description of *Megacerops coloradensis.*] Proc. Acad. Nat. Sci. Philadelphia, vol. 22, pp. 1–2.

[On *Poicilopleuron* and other fossils, *Clidastes, Leiodon, Emys,* etc.] Idem, pp. 3–5.

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[On fossil bones of extinct giant sloths resembling *Mylodon robustus.*] Proc. Acad. Nat. Sci. Philadelphia, vol. 22, pp. 8–9.

[On *Dromatherium sylvestre.*] Idem, p. 9 (12 lines).

[On the reptile from the Cretaceous formation near Fort Wallace, Kansas, described by Professor Cope under the name of *Elasmosaurus platyurus.*] Idem, pp. 9–10.

[On a fossil mandible, *Palriofelis ulta,* from Fort Bridger, Wyoming.] Idem, pp. 10–11.

[Observations on *Ichthyodorulites.*] Idem, p. 12.

[On *Megalonyx jeffersoni* and *Bison antiquus.*] Idem, p. 13.

[On *Discosaurus* and its allies.] Idem, p. 18. American Journ. Sci., 2d ser., vol. 50, pp. 139–140.

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[Description of the internal generative organs of a hog.] Proc. Acad. Nat. Sci. Philadelphia, vol. 22, p. 65.

[On fossil bones from the Pliocene formation in Dakota and Nebraska.] Idem, pp. 65–66.

[On fossil Mammalia from Idaho, Utah, and Oregon.] Idem, pp. 66–67.

[On *Hadrosaurus* and its allies.] Idem, pp. 67–68.

[On the family Anguillulidæ, a new species of vinegar eel.] Idem, pp. 68–69.

[On fossils from the vicinity of Burlington, Kansas, and from the Rocky Mountains.] Idem, pp. 69–71.

[On the difference between animals of the same species inhabiting Europe and America.] Idem, p. 72.

[On a fossil lower jaw of a large ruminant, *Ovibos cavifrons.*] Idem, p. 73.

[On *Nothosaurops occiduus.*] Idem, p. 74.

[Description of *Nephelis punctata,* a new leech.] Idem, pp. 89–90.

[On Mastodon remains in the Warren Museum, the museum at Cambridge, and at Amherst College, and on a new species of Mastodon.] Idem, pp. 96–99.

[On *Crocodilus elliotti,* a new species of crocodile.] Idem, p. 100.

[Observations on *Manayunkia* and *Urnatella.*] Idem, pp. 100–102.

[On fossils from Sweetwater River, Wyoming.] Idem, pp. 109–110.

[On fossils from Bridge Creek, Oregon.] Idem, pp. 111–113.

[On *Cordylophora.*] Idem, p. 113 (13 lines).

[Description of *Palæosyops paludosus, Microsus cuspidatus,* and *Notharctus tenebrosus,* etc., and observations in reference to fossils from Fort Bridger.] Idem, pp. 113-114.

[On *Graphiodon vinearis* and *Crocodilus elliotti.*] Idem, p. 122.

[On *Emys jeanesi, Emys haydeni, Baëna arenosa, Saniwa ensidens,* with a description of the new fossil species.] Idem, pp. 123–125.

[Observations on fossils from Table Mountain, Cal., submitted for examination by Prof. J. D. Whitney.] Idem, p. 125.

[On *Lophiotherium sylvaticum,* a fossil pachyderm from Wyoming.] Idem, p. 126.

[On *Protohippus* and *Hippidion.*] Idem, p. 126.

Observations on a human inferior *Maxilla,* having imbedded in its substance a perfect third molar tooth. Idem, p. 133 (12 lines).

On reversal of the viscera in the human subject. Idem, p. 134 (8 lines).

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[On fossil bones from California—Mastodon, Horse, etc.] Proc. Acad. Nat. Sci. Philadelphia, vol. 23, p. 50.

[On *Tænia mediocanellata.*] Idem, pp. 53–55.

[On extinct fossil turtles from Wyoming. *Anosteira ornata* and *Hybemys arenarius.*] Idem, pp. 102–103.

[On Polydactylism in a horse.] Idem, p. 112.

Remains of mastodon and horse in North Carolina. Idem, p. 113.

Remains of extinct mammals from Wyoming [*Trogosus* and *Sinopa*]. Idem, pp. 113–116.

Remarks on a fossil *Testudo* of Wyoming. Idem, p. 154.

Remarks on supposed fossil turtle eggs. Idem, pp. 154–155.

Remarks on the Garnets of Green's Creek, Delaware Co. Idem, p. 155.

Remarks on donation of fossils from Wyoming. Idem, p. 197.

Remarks on mastodon, etc., of California. Idem, pp. 198–199.

Note on *Anchitherium.* Idem, p. 199 (8 lines).

Remarks on fossil vertebrates from Wyoming. Idem, pp. 228–229.

Notice of some extinct rodents. Idem, pp. 230–232.

Remarks on the minerals of Mount Mica. Idem, pp. 245–247.

Remarks on fossils from Oregon. Idem, pp. 247–248.

Flies as a means of communicating contagious diseases. Idem, p. 297.

Notice of some worms (*Dibothrium cordiceps, Hirudo, Gordius*). Idem, pp. 305–307.

Tænia caused by the use of new beef. American Journ. Med. Sci., 2d ser., vol. 44, p. 293.

Remarks on some curious sponges. American Nat., vol. 4, pp. 17–22, 3 figures.

1872.

On a mite in the ear of the ox. *a.* Note on *Gamasus* of the ox. Proc. Acad. Nat. Sci. Philadelphia, vol. 24, pp. 9 and 138.

Notice of corundum. Idem, p. 19.

Remarks on fossils from Wyoming. Idem, pp. 19–21.

Remarks on some extinct mammals [from the Tertiary of Wyoming]. Idem, p. 37.

Remarks on some extinct vertebrates [from Niobrara River, *Felis augustus, Oligosimus grandævus,* and *Tylosteus ornatus*]. Idem, pp. 38–40.

Remarks on mastodon from New Mexico. Idem, p. 142.

On a new genus of extinct turtle (*Chisternon*). Idem, p. 162.

On some remains of Cretaceous fishes. Idem, pp. 162–164.

On *Artemia* from Salt Lake, Utah [and on fossil shark's teeth]. Idem, pp. 164–166.

Remarks on fossil shark teeth. Idem, p. 166.

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